PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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THE LOOK BOX

WHEN the influence of the Petroleum Administration for War was used to prevent the Petroleum Industry War Council from expressing its attitude toward the Anglo-American oil pact, PAW thereby changed its status from that of an agency of government into a bureau.

Now It's a Bureau

It has been a matter of pride within the industry as well as within government that PAW had so conducted its affairs as not to deserve the stigma of bureaucracy. PIWC enjoyed its pleasant relationship, as an advisory body, voluntarily set up and approved by Harold L. Ickes and other PAW officials.

That this relationship had much to contribute to the workings of PAW is undoubted. As an agency, PAW has nothing in government superior in effectiveness. The record speaks in high approval.

But an oil pact came along and gained the status of moving to a matter of approval. It is accepted that a majority of those within the petroleum industry do not approve of the oil pact. It was logical that PIWC would in time have occasion to reveal its attitude toward the oil pact.

At that point PAW ceased to be a cooperative agency. It made its influence so effective that PIWC declined to take action. That is the way of a bureau, and not the way of an agency.

In effect the action of PAW is that it welcomes cooperation when it is in keeping with what PAW considers proper. Otherwise, no cooperation is wanted.

It is not logical that PAW, itself, is vitally concerned as to the final status of the international oil pact. That is the reason many believe that PAW in its warning to PIWC was carrying out instructions from some other agency of the federal government.

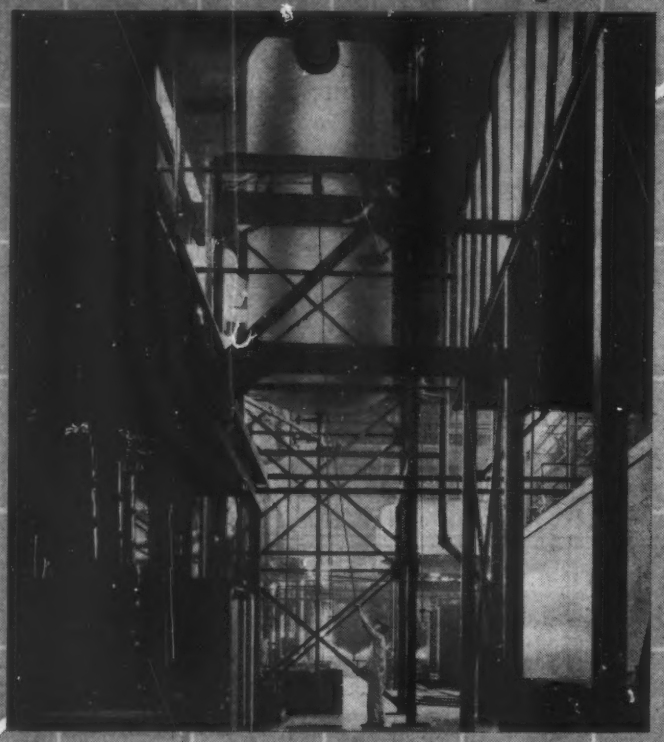
When bureau befriends bureau the result is bureaucracy.

SENATOR Guy M. Gillette of Iowa, perennial antagonist of the oil industry, charges the industry has conspired to take the synthetic rubber industry away from alcohol. As a member of the farm bloc, the Senator of course is interested in boosting the market for grain. Basis for his charge of conspiracy comes from orders by the rubber administrator that production of butadiene from petroleum be stepped up during the fourth quarter. The Senator further intimates that the oil industry is curtailing gasoline deliveries for benefit of aggression in the rubber matter.

Senator In the Dark

What the Senator has overlooked is that the oil industry did not seek and does not know if it wants the synthetic rubber business. Total demand for the ingredient the industry can supply for that purpose is so small a part of the industry's volume that it is of little consequence. Plants which have been built to make rubber ingredients were erected under government urging as a part of the war effort, and the oil industry contributed largely and eagerly of its technical talent toward perfecting processes for making synthetic rubber—whether grain or petroleum is the starting point. It was apparent during the construction period that preference was given the alcohol plants while petro-

Dowtherm on the job!



Four years of starts and stops—a tough test of flexibility!

The picture above shows a Dowtherm installation used in the deodorization of vegetable oils by a processor located in the Middle West. In addition to the *accurate* control of heat, this operation calls for the frequent starting-up and shutting-down of their 4,000,000-BTU/hr system, a requirement which, they report, Dowtherm has ideally fulfilled during its several years of operation. That is *flexibility*. And since the installation of Dowtherm, early in 1940, it has been necessary to add only one drum of Dowtherm fluid as replacement. That is *economy*.

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leum plants waited for materials. The fact that grain has a farm bloc in Congress and oil does not, may have had something to do with that.

Now that the plants are built, petroleum plants have not been working at capacity because alcohol has been carrying the load. Economiss have been laid aside because by making less butadiene the oil industry can make more aviation gasoline. This will not continue always. After the war, synthetic rubber will be made from the cheapest ingredient available unless there is more government interference than is hoped for. When that happens, alcohol from grain will have small chance against sugar refuse as a source of alcohol. Or it might be that petroleum will supply alcohol and it can make ethyl alcohol more cheaply than it can be made from grain at the price the farmer wants.

Alcohol has been available for making rubber at the expense of the beverage business. Makers of alcohol would prefer to get back to their own business. Because of its cheapness, butadiene from petroleum probably will be used for rubber after the war. But so far as seeking to take something away from the farmers—the oil industry was asked to make butadiene and has been too busy with that and other war emergencies even to find out if it will want the business permanently.

Is It Wanted?

UNLESS the men and women who make up the petroleum industry are satisfied with provisions of the Anglo-American petroleum treaty proposal they should register their objections, especially to members of Congress. It is foolhardy to expect others to shape the proposal or to prevent its final approval. This document will permit government to have further control over the jobs and investments in the domestic oil industry. Those having the jobs and the investments should study and act accordingly.

Two objections seem evident to PETROLEUM REFINER. One is the freedom of authority it would give to a commission. Several readings of the proposal leave the first conviction—that a few men would have powers for doing to the industry what no corporation would dare attempt.

The other is that the proposal is in the final analysis nothing but a cartel. The proposal would empower a commission to determine the market for oil and to supervise distribution. When this is done by an industry it is branded as a cartel, and the parties to the agreement are prosecuted on a charge of violating the anti-trust laws of the United States.

Now the government of the United States would be empowered to do what its laws condemn.

When a commission comes to determining the amount of a product to be sold, it in turn must do something about how much of the product is available. That is where the decisions of the commission finally will have influence on the jobs and investments within the oil industry in the United States. The only way a market can be divided is by dividing production.

Greener Pastures

ONE of the shortcomings of mankind is the assumption of each individual that he has been the victim of a circumstance whereby another has profited. Because of this attitude men combine into cliques, somewhat circumscribed by disaster. It even pervades an industry, such as petroleum. It was common admission in recent years for the marketing department of a major company to contend that its profits were hampered by action of the refining division, which in turn might blame its plight on production.

Recently we have had the sorry spectacle of men who expect aid from the federal government so as to permit readjustment. Owners of plants have contended that they should have some money benefits, so as to shift production back to goods for peacetime consumption. The ones who are making the war goods likewise want a period of unemployment compensation so as to readjust themselves in peacetime employment.

Each contends that the other has enjoyed abnormal profit during the war, consequently the assistance is justified. Neither side seems to have considered the proposition of saving something for the readjustment. That can be done, even under existing tax payments.

This age needs a wave of willingness to accept responsibility. No war is going to be fought in luxury and ended without penalty, even for the victor.

Out of the Laboratory

IT WOULD be appropriate if the working forces of the refining plants turned each day and gave a figurative bow to the laboratory. Out of research has come to the development which has required expanding employment, and fortunately the employment in refining has been at an ever-rising wage scale.

In the October PETROLEUM REFINER Gustav Egloff set out the place of invention in the petroleum industry. In this issue Thomas Midgley has a paper of similar nature. These outstanding scientists have messages the working forces of refining plants should study.

What they offer is proof that jobs come out of the research laboratory.

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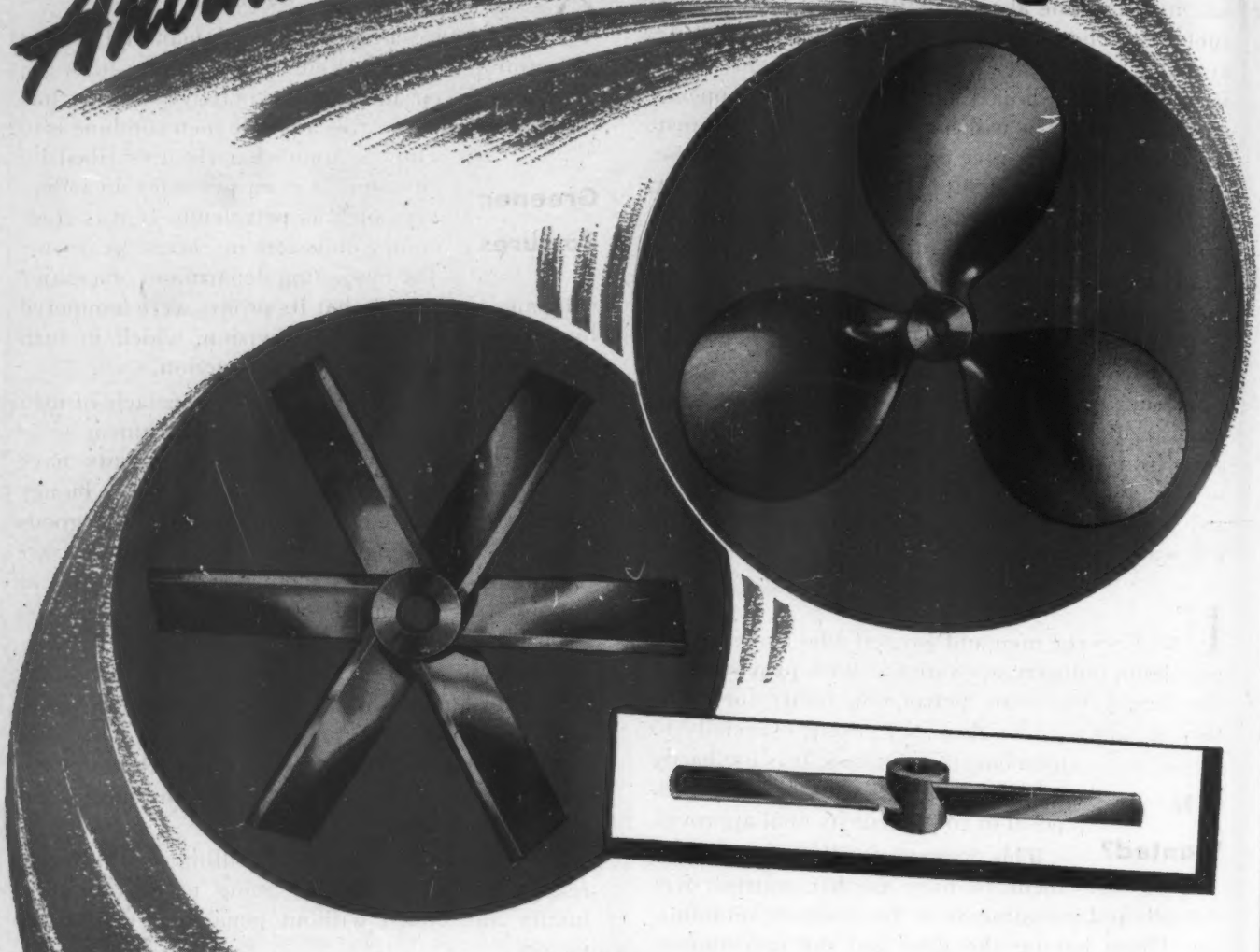

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Butane Dehydrogenation By the Houdry Process

R. C. LASSIAT, Catalytic Development Corporation, and
F. D. PARKER, Bechtel-McCone Corporation

THE Houdry adiabatic catalytic dehydrogenation process has made available to the petroleum refining, petrochemical and natural gasoline industries a means for converting paraffins from ethane through pentane to olefins and di-olefins. Other dehydrogenation reactions of commercial interest can be handled by the process. Commercial operation of the Houdry adiabatic dehydrogenation process for the production of butadiene proves the feasibility of the process. Large potentialities for production of chemicals from petroleum are opened up, and it is therefore expected that the process will find application in postwar dehydrogenation projects.

This paper was presented at the Fall Meeting of the California Natural Gasoline Association, Los Angeles, October 13, 1944.

DEHYDROGENATION of light hydrocarbons has attracted considerable attention in recent years as a means for making the large quantities of natural-gas constituents available for manufacture of petroleum constituents, chemicals, and chemical intermediates. At the beginning of the present war, major interest was focused on the production of butadiene —the principal constituent of Buna-S synthetic rubber. Buna-S rubber production represents approximately 83 percent of the total planned United States synthetic rubber production.[11]

Previous Work

The literature contains numerous references to theoretical and laboratory studies of dehydrogenation yields, operating conditions, and catalysts.[6,8,10] It has been known for a number of years that normal butane can be dehydrogenated to butylene and butadiene at elevated temperatures in the presence of metallic oxide catalysts. One of the catalysts which is most attractive from the point of view of cost, activity, and ruggedness is chromic oxide supported on alumina.[1,2,3,9] While the literature indicates that attractive yields are obtainable with this catalyst, the details of catalyst manufacture, operating conditions, heat balances, process and mechanical features of the equipment in which the reaction can be carried out commercially had to be developed by technical groups active in the field.[4,5,7]

The basic chemistry of the dehydrogenation reaction is briefly illustrated below:

$$\text{n-}C_4H_{10} \longrightarrow \text{n-}C_4H_8 + H_2$$
(normal butane) ⟵ (normal butylene + hydrogen)
$$\text{n-}C_4H_8 \longrightarrow C_4H_6 + H_2$$
(normal butylene) ⟵ (butadiene + hydrogen)

The above reactions occur to an appreciable extent only at temperatures above 900° F.

Table 1 presents equilibrium values for mol fraction of n-butane, butene-1, and butadiene 1, 3 as calculated from thermodynamic considerations by Gruse and Stevens.[6]

Table 2 lists equilibrium olefin concentrations as calculated from data of Gruse and Stevens,[6] Kassel, and Pitzer. The work of the latter authors on this subject is summarized by Grosse and Ipatieff.[4] While the absolute values of equilibrium constants are at variance, the magnitude of per-pass conversions is indicated.

TABLE 1
N-Butane Dehydrogenation Equilibrium*

Temperature			EQUILIBRIUM MOL FRACTION							
			n-Butane		Butene-1		Butadiene-1, 3		Hydrogen	
K	C	F	1 Atm.	0.25 Atm.	1 Atm.	0.25 Atm.	1 Atm.	0.25 Atm.	1 Atm.	0.25 Atm.
600	327	621	.97	.96	.015	.02	...	...	.015	.02
700	427	801	.72	.58	.14	.20	...	.01	.14	.21
800	527	981	.42	.20†	.27	.34	.01	.04	.30	.42
900	627	1,161	.20	.02	.29	.30	.07	.13	.44	.55
1,000	727	1,341	.01	.01	.22	.09	.18	.27	.59	.63

*"Round-ed Off" values from Gruse and Stevens. †Adjusted.

TABLE 2
Comparison of Calculated Equilibrium Olefin Concentrations in Butane Dehydrogenation at Atmospheric Pressure

TEMPERATURE			Equilibrium Olefin Concentration (Mol. Percent)		
°K	°C	°F	Gruse and Stevens*	Kassel†‡	Pitzer†‡
700	427	801	14	8.3	11.4
773	500	932	25	20.6	24.5
873	600	1,112	34	40.3	41.9
1,000	727	1,341	40	48.7	48.7

*Includes butene and butadiene. †Butene only. ‡Reported by Grosse and Ipatieff.

Description of the Houdry Adiabatic Dehydrogenation Process

Dehydrogenation is accomplished by passing the preheated hydrocarbon vapors under controlled conditions of space velocity, temperature, and pressure over catalysts of the chromic oxide (Cr_2O_3)-alumina type. A study of their catalytic behavior as related

to their physical and chemical characteristics has resulted in the preparation of materials of controlled and highly selective activity suitable for various dehydrogenation charging stocks described in this paper.

During the reaction period a large amount of heat is absorbed due to the heat of reaction which is of the order of 1000 Btu's per pound of butene produced from butane, 2000 Btu's per pound of butadiene produced from butane. In addition to products of dehydrogenation, fixed gas is liberated and coke is deposited on the catalyst. This coke has to be burned

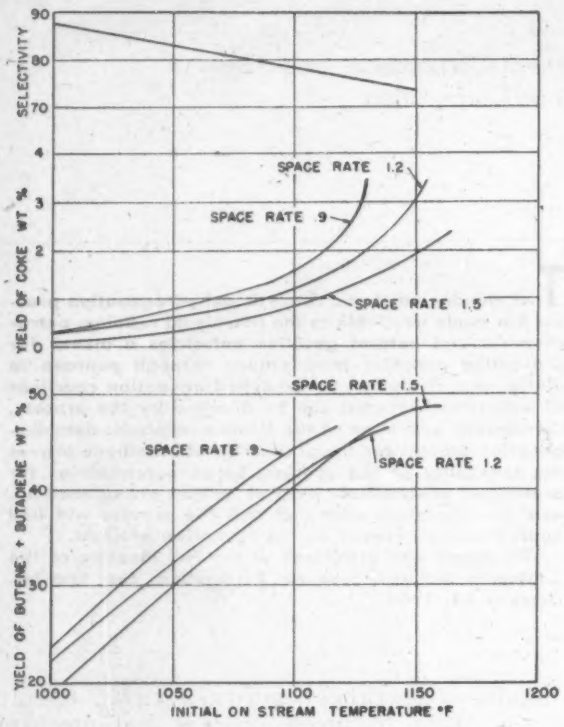


FIGURE 1
Effect of temperature at various space rates on the dehydrogenation of butane (Seven inches of mercury, absolute).

off periodically in order to restore the initial catalyst activity.

The characteristic feature of the Houdry dehydrogenation process is that the operating conditions are so chosen that the heat used for the reaction during the onstream period is substantially the same as the heat developed by the combustion of the coke deposit. Futhermore, the heat capacity of the catalyst bed is controlled by mixing with the active catalyst in the form of pellets, a catalytically inert material. Several sources of such inert material are available, but secrecy orders do not permit disclosure of further details at this time. The inert material acts as a heat-storage medium, absorbing during the regeneration cycle the heat liberated by the combustion of the coke deposit, with a consequent increase in temperature of the bed, and releasing that heat to the reacting hydrocarbons during the dehydrogenation period, with decreasing temperature.

The preferred condition is that the heat of reaction be slightly greater than the heat of combustion. The heat deficiency and the desired operating temperature are controlled by the adjustment of reactant and air temperatures, and by the use in the regeneration cycle of an amount of air substantially greater than the combustion requirements. The latter equalizes differences in temperature in a large size bed due to heat losses in parts adjacent to the wall, imperfect flow distribution of fluids throughout the bed, minor inequalities in catalyst activities and heat capacities, and the like. The air used being near atmospheric pressure, the cost of pumping is nominal and the heat can be recovered in waste-heat boilers.

The inert material possesses a very large surface and the heat exchange between this material, the catalyst pellets, and the reactants takes place with very small temperature differences.

The on-stream periods are kept very short, namely, between 7 and 15 minutes. By this means the temperature variation during the cycle is small, usually within 50° F. covering the optimum range of temperature necessary to insure high conversions; also the total coke deposits on the catalyst is limited to a low value, insuring high catalyst activity throughout the cycle.

The advantages derived from the use of this scheme are as follows:

1. Expensive special alloy heat-exchange equipment within the reactor is eliminated and the reactor construction is cheap.
2. Reactants are introduced at substantially reaction temperature, eliminating problems of pre-thermal cracking.
3. The temperatures are controlled within the desired range of reaction. No excessive temperatures are encountered during the regeneration period, thus protecting catalyst life.
4. Regeneration can be accomplished by the use of fresh air, with no limitation of oxygen concentration, and there is no problem of recirculating hot gases.
5. High conversion per pass and high product concentration are feasible.

Extensive laboratory and pilot-plant experimentation as well as continuous commercial operation have proved the practicability of this unique development.

Discussion of Laboratory Data on the Effect of Variables in the Dehydrogenation of Butane and Butane-Butene Cuts

Temperature

Dehydrogenation equilibria referred to previously indicate that high temperatures are required for conversions of commercial interest. These equilibria are such that mono-olefins can be produced economically at substantially atmospheric pressure and temperatures of the order of 1050-1100° F. For the production of di-olefins, however, not only high temperatures but also low partial pressures are necessary. These can be attained by either diluting the reactants with some inert gas or vapor or operating at low absolute pressure. Considerations of cost usually preclude the use of gases. Steam has been found to be detrimental to the reaction, as well as to catalyst life. Operating at reduced pressures as low as 2½ pounds absolute has been found practical for the production of di-olefins and the engineering problems connected with this type of operation have been readily solved.

Figure 1 shows the effect of temperature at various space rates on the dehydrogenation of butane. These data were obtained during the study of butadiene production and were, therefore, obtained at reduced pressure. Of interest is the rapid increase of yield with temperature, the decrease in selectivity, and the rapid increase in coke formation above 1100° F.

Space Rate

Space rate can be varied quite widely without substantially affecting the yield of products. The

side reactions, particularly the coke formation, are cut considerably by increased space rates and this factor is the mose effective way to balance out heat of reaction with heat of carbon combustion.

Figure 2 shows the yield of butadiene from a charging stock containing 35 percent n-butene and 65 percent butane at constant pressure, constant temperature, and varying space rate. The upper curves show the calculated heat of reaction and heat of combustion, respectively. The point at which the curves cross is the point of operation at "adiabatic condition."

These data were obtained in a laboratory isothermal unit.

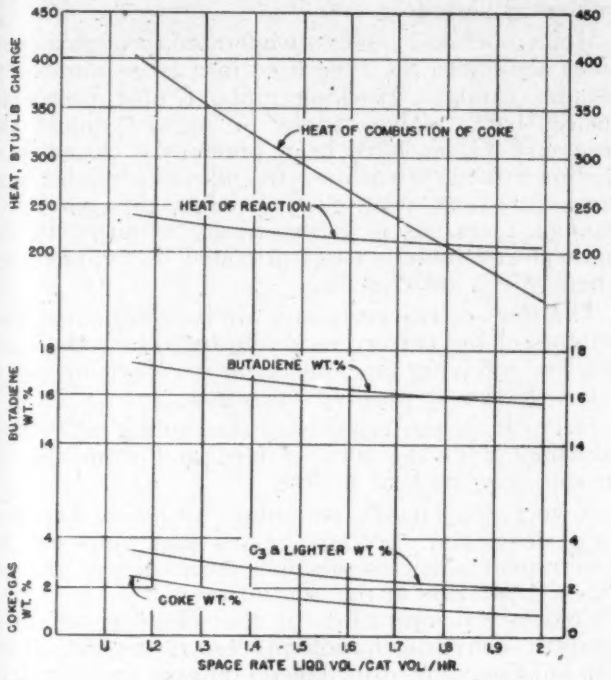


FIGURE 2

Yield of butadiene from a charging stock containing 35 percent n-butene and 65 percent butane at constant pressure, constant temperature, and varying space rate. (Temperature 1100 F., pressure 5 inches mercury, absolute).

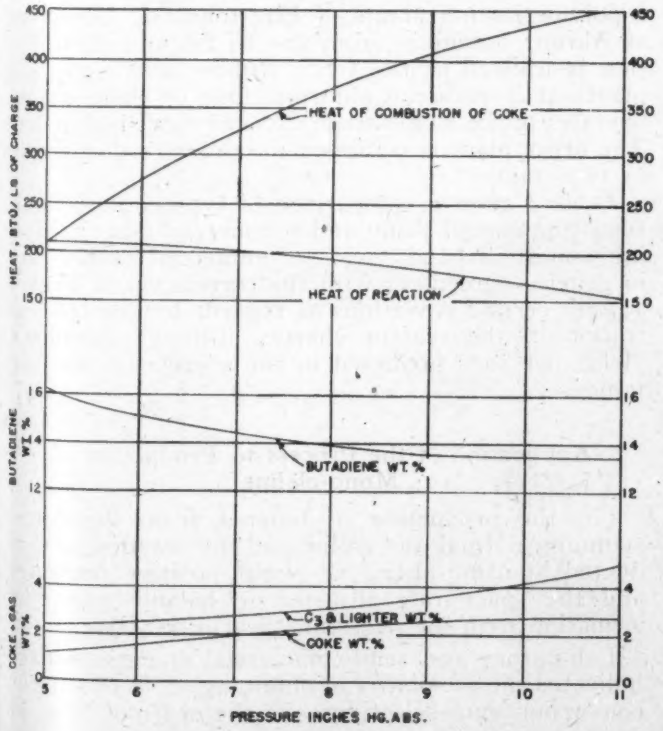


FIGURE 3

Effect of varying pressures at constant temperature and space rate on charging stock containing 35 percent n-butene and 65 percent butane.

Pressure

Within the range of pressures necessary to effect the desired reaction an adjustment in pressure also provides means of controlling the coke deposit in relation to the heat of reaction.

Figure 3 shows the effect of varying pressure at constant temperature and space rate on same charging stock as above, i.e. 35 percent n-butene and 65 percent n-butane. Again it can be seen that the curves showing heat of reaction and heat of combustion cross at the operating point for the chosen space rate and temperature.

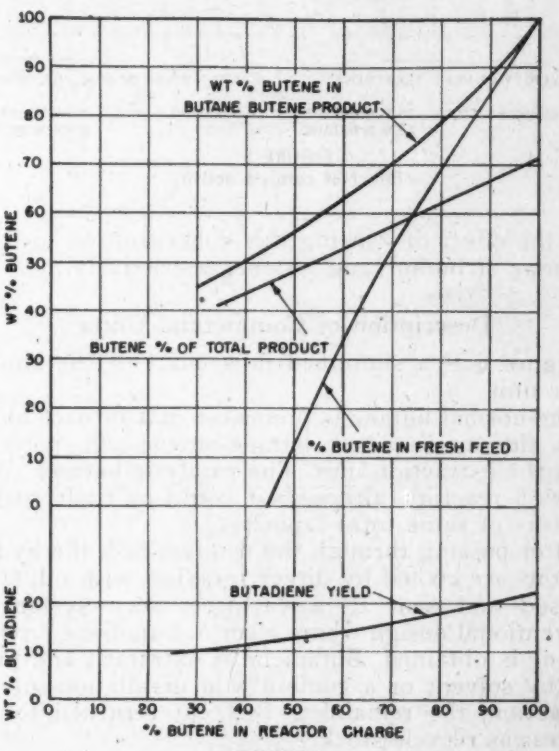

WT % BUTENE IN BUTANE BUTENE PRODUCT
WT % BUTENE
BUTENE % OF TOTAL PRODUCT
% BUTENE IN FRESH FEED
BUTADIENE YIELD
WT % BUTADIENE
% BUTENE IN REACTOR CHARGE

FIGURE 4

Relationship between butene in original fresh feed, butene in composite feed to reactor, butene in recycle stock, and butadiene in reactor product. (Space rate 1, pressure 5 inches mercury, absolute).

Feed Composition

Figure 4 shows the relationship between butene in original fresh feed, butene in composite feed to reactor, butene in recycle stock, and butadiene in reactor product. It shows the yields of products from once-through operation (lower scale) and the yield product distribution in recycling operations. For example, starting with n-butane (0 percent butene in fresh feed), the reactor charge builds up to approximately 44 percent butene and the yield of butadiene per pass is 12.5 percent.

Catalyst Activity

From the above considerations, it is evident that the catalyst must possess enough activity to give good conversion with a controlled coke deposit. Also, the activity must be oriented towards the maximum conversion of butane resulting in higher butene con-

centration in reactor charge and subsequently higher conversions to butadiene per pass.

Figure 5 shows the effect of catalyst heat treatment on butadiene and coke yield for a given concentration of chromic oxide on the alumina support

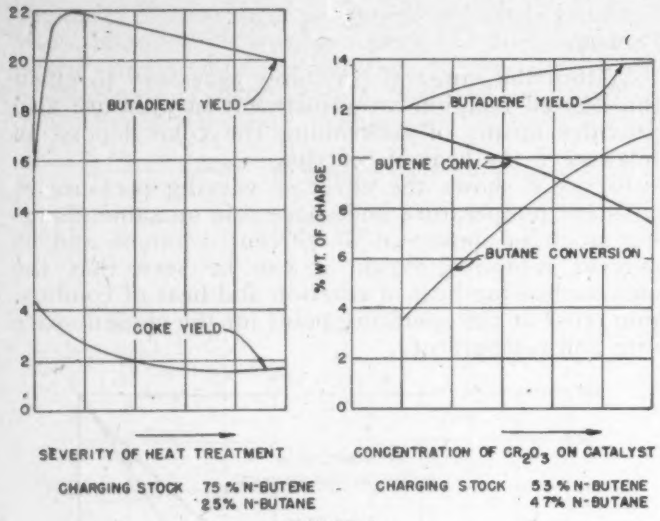


FIGURE 5
Effect of catalyst activity

and the effect of varying this concentration on conversions of butane and butene, respectively.

Description of Commercial Units

Figure 6 is a simplified flow chart of the single-stage unit.

The normal butane is preheated in a furnace along with the unconverted butane-butene cut recycled from the extraction unit. The catalytic battery comprises 6 reactors, although it could be built with 3 reactors of same total capacity.

After passing through the catalyst bed, the hydrocarbons are cooled by direct spraying with oil, compressed and sent to a vapor-recovery system of conventional design where a cut of butadiene-butene-butane is obtained. Butadiene is extracted and purified by solvent or a combination distillation-solvent extraction, the remaining B-B cut returned to the process as recycle stock.

TABLE 3
Comparison of Laboratory, Semi-Commercial and Commercial Units Houdry Single-Stage Butadiene Process

UNIT	Pilot Plant		Semi-Commercial		Commercial	
Catalyst capacity, cu. ft.	0.35		11.7		1,060	
Number cases	1		1		6	
Operating Conditions:						
Cat. temp., on-stream, °F. ave.	1,060		1,124		1,100	
Cat. temp., off-stream, °F. ave.	....		1,083		....	
Cat. temp., °F. ave.	....		1,103		1,070	
Pressure, inches Hg. abs.	5.0		4.9		4.9	
Time on-stream, mins.	10.0		7		10	
Charge temperature, °F.	....		1,085		1,075	
Regeneration air temp., °F.	....		1,140		1,075	
Charge rate, V/V/hr.	1.9		2.8		2.7	
Regeneration air rate, CFM/liter	0.5		1.8		2.2	
Yields, Percent Weight:	**Charge**	**Prod.**	**Charge**	**Prod.**	**Charge**	**Prod.**
C_3 and lighter	....	1.6	4.6	7.8	2.2	3.7
Isobutane	2.5	3.7	3.1	1.6	0.9	1.9
Isobutene	....	3.5	1.5	2.3	2.1	2.5
n-Butene	26.8	36.8	28.9	26.9	23.1	23.1
n-Butane	70.5	42.9	62.7	46.3	67.0	53.3
Butadiene	0.2	10.1	....	11.8	3.8	12.7
C_5 Plus	....	0.4	....	0.8	0.9	1.7
Coke	....	1.0	....	2.5	....	1.2
	100.0	100.0	100.0	100.0	100.0	100.0

After the on-stream period, air is introduced to burn off the coke deposit. This air is preheated by direct combustion of fuel in the stream, and the pressure at the blower discharge is controlled by the pressure drop through the system which is generally of the order of 2-3 pounds per square inch.

At the end of the regeneration period, the air remaining in the reactor is evacuated by a steam jet, prior to introduction of hydrocarbons for another on-stream period.

Motor-operated valves are operated through a cycle timer similar to the type used in a large number of Houdry catalytic cracking units. Proper interlocks insure that a valve cannot be opened unless the necessary valves have been previously closed, precluding mixing of various streams. As a further precaution against mixing of streams through valve leakage, inert gas is automatically admitted in the bonnets and lantern rings provided in the packings when valves are closed.

The flow of reactants and air is continuous; two reactors of the battery receiving hydrocarbons while two are receiving air, and the last two being under valve change or purging operation.

Heat can be recovered from the cooling oil by heat exchange with the furnace feed and from the air stream in waste-heat boilers.

A very satisfactory two-stage operation has also been developed. Secrecy restrictions imposed by government agencies preclude discussion of the details of operation at the present time.

Commercial operation of the Houdry adiabatic catalytic dehydrogenation process is carried on by Sun Oil Company at its Toledo refinery and Standard Oil Company of California at its El Segundo refinery. Both of these facilities were built by Defense Plant Corporation, and are operated by the respective oil companies for the account of Rubber Reserve Company. Butadiene production from the Toledo plant is utilized in the production of GR-S rubber at the copolymerization plants of Firestone and Goodyear at Akron; butadiene from the El Segundo installation is utilized at the U. S. Rubber and Goodyear plants at Torrance, California. One of these plants operates in the single-stage cycle as described above. The other plant is equipped to operate either single or two-stage.

Table 3 gives a comparison of typical pilot-plant, semi-commercial plant, and commercial-plant operating conditions and yields. Commercial results are in general agreement with the correlation of Figure 4, with certain deviations as regards butene concentration in the reactor charge, although butadiene yields per pass predicted in the correlation are obtained.

Application of the Process to Production of Mono-olefins

For the production of butenes from the corresponding normal and isobutane, the reaction is conducted at atmospheric or slight positive pressures and the space rate adjusted to balance the coke formation with the necessary heat of reaction.

Laboratory and semi-commercial operations have indicated the possibility of obtaining up to 50 percent conversion with selectivities of the order of 70 to 75 percent.

The plant flow sheet is substantially the same as the one-stage unit. Line sizes and compression re-

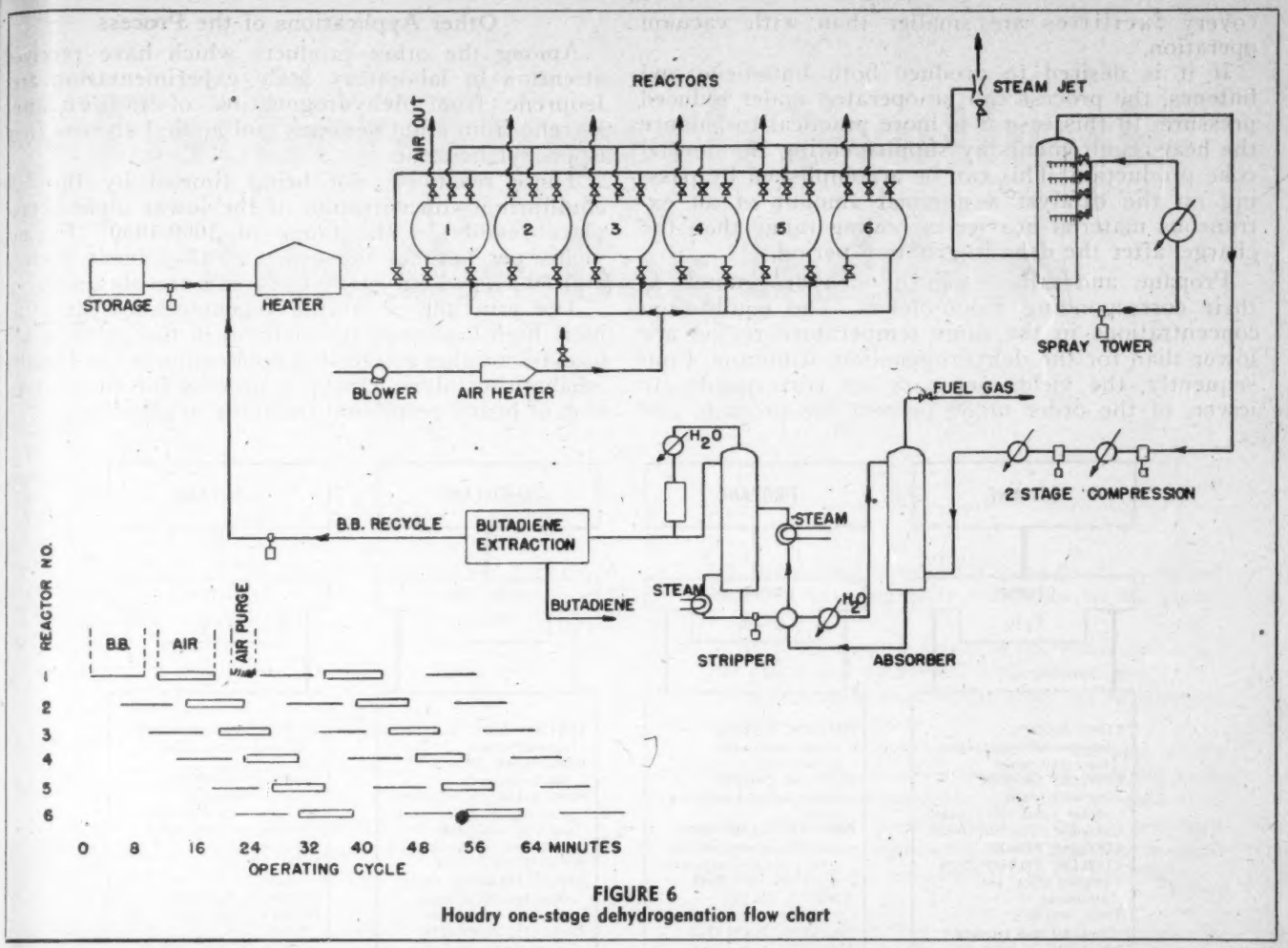
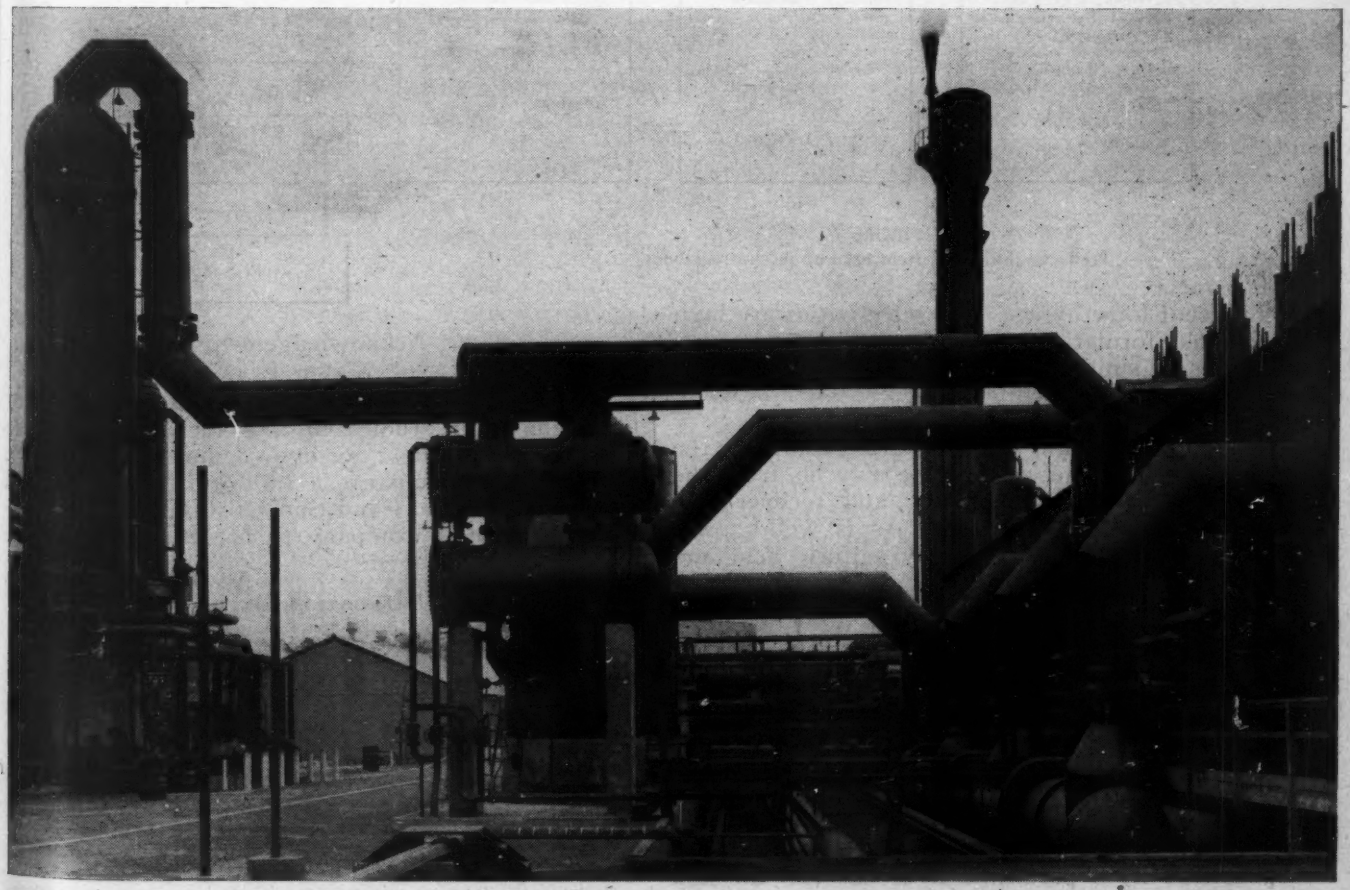


FIGURE 6
Houdry one-stage dehydrogenation flow chart



Butadiene plant of Standard Oil Company of California, El Segundo, where the Houdry adiabatic dehydrogenation process is used

covery facilities are smaller than with vacuum operation.

If it is desired to produce both butadiene and butenes, the process can be operated under reduced pressure. In this case it is more practical to balance the heat requirements by supplementing the normal coke production. This can be accomplished by passing on the catalyst a nominal amount of an extraneous material heavier in boiling range than the charge, after the dehydrogenation period.

Propane and ethane can be dehydrogenated to their corresponding mono-olefins. The equilibrium concentrations in the same temperature region are lower than for the dehydrogenation of butane. Consequently, the yields per pass are correspondingly lower, of the order of 30 percent for propane and

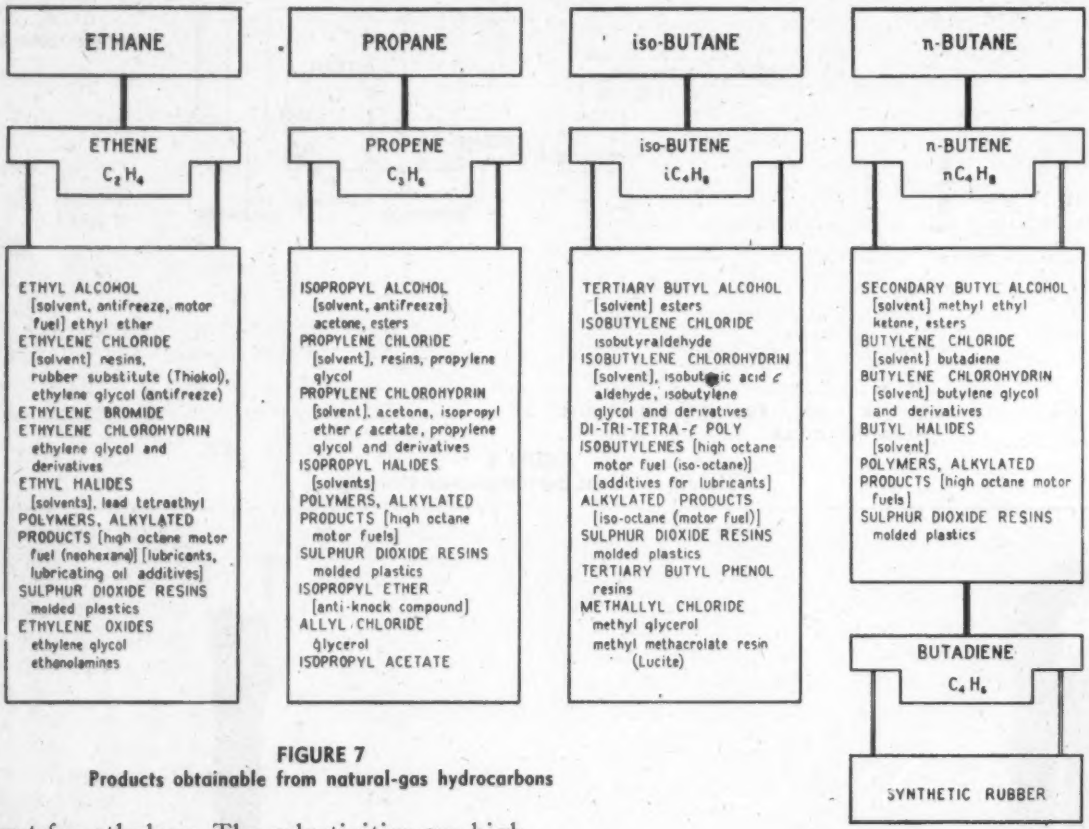


FIGURE 7
Products obtainable from natural-gas hydrocarbons

16-20 percent for ethylene. The selectivities are high and the coke formation low at atmospheric pressure, and means of supplementing the coke formation as described above are used.

In order to obtain ultimate yields, it is necessary to provide means for selectively removing the ethylene or propylene, as the case may be, from the reactor effluent after quenching and recovery by compression and or absorption. As is well-known, the ethylene can be removed by sulfuric acid and synthetic ethyl alcohol produced by hydrolysis. Propylene can be similarly removed to form isopropyl alcohol on subsequent hydrolysis. It is therefore seen that a whole field of potential chemical industries is opened up by catalytic dehydrogenation of the relatively inert paraffin constituents of natural gas and gasoline to olefins or di-olefins, which can be reacted in a number of ways to produce a large number of products. Figure 7, from Bureau of Mines Information Circular 7108, diagrammatically shows a few of the intermediate and chemicals which can be produced from paraffinic hydrocarbons through the initial step of dehydrogenation.

Other Applications of the Process

Among the other products which have received attention in laboratory scale experimentation are: Isoprene from dehydrogenation of isopentane; styrene from ethyl benzene, and methyl styrene from isopropyl benzene.

These reactions, not being limited by the low equilibrium concentration of the lower olefins, take place readily in the range of 1000-1050° F., and yields per pass of the order of 45 percent styrene and 60-65 percent methyl styrene are obtained.

The principle of storing regeneration heat in an inert high-heat-capacity medium in the catalyst bed has still another interesting application in the Houdry adiabatic catalytic cracking process for the conversion of heavy petroleum fractions to gasoline.

Acknowledgement

The authors wish to express their appreciation of helpful suggestions made during early pilot-plant and semi-plant studies by the technicians of the following companies: Socony-Vacuum Oil Company, Standard Oil Company of California, Standard Oil Company (Indiana) and Sun Oil Company. Permission of Sun Oil Company to use commercial-plant data is acknowledged.

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Fischer-Tropsch Synthesis And the Gas Industry

V. I. KOMAREWSKY and C. H. RIESZ, Institute of Gas Technology, Chicago

THE extent of American petroleum resources has been a controversial subject for many years. However, there is a unanimous agreement that processes for the production of alternative liquid fuels should be investigated thoroughly in the interests of national defense. Of the many processes which have been suggested, the following are the most important:

1. Hydrogenation of coal
2. Low-temperature carbonization
3. Distillation of oil shale
4. Treatment of tar sands
5. Fischer-Tropsch synthesis

Of these processes, the hydrogenation of coal, low-temperature carbonization and the Fischer-Tropsch synthesis are of interest to the gas industry. The Fischer-Tropsch process, however, is of particular interest to the gas industry because it alone possesses all of the following desirable features:

1. A *new*, large scale use of gas
2. *Low*-temperature, *low*-pressure process
3. Important yields of high-quality gas are received as a by-product
4. The hydrocarbon products can be used for *water-gas enrichment* in place of petroleum oils
5. Potential consumption of *off-peak* gas production

The Fischer-Tropsch synthesis is of value to the manufactured gas interests because of its potential ability to utilize off-peak water-gas production, e.g., during the summer months. Figure 1 shows the monthly variation in total sales of manufactured gas in the United States.[1] Since the peak loads frequently are met by the use of stand-by water-gas sets, certain units may be idle most of the year. The natural-gas companies have accepted more space-heating loads than the manufactured-gas companies and consequently, the sale of natural gas is even more seasonal (Figure 2).[1] The Fischer-Tropsch synthesis is a vital concern of the natural-gas interests also because natural gas is readily converted to mixtures of carbon monoxide and hydrogen by a number of reactions, among which are included:

$$CH_4 + H_2O \longrightarrow CO + 3H_2 \quad (1)$$
$$CH_4 + CO_2 \longrightarrow 2CO + 2H_2 \quad (2)$$
$$CH_4 + \tfrac{1}{2}O_2 \longrightarrow CO + 2H_2 \quad (3)$$

From such mixtures, or modifications thereof, valuable products could be synthesized by means of the Fischer-Tropsch synthesis.

In the entire gas industry, therefore, carbon monoxide-hydrogen mixtures for use in the Fischer-Tropsch synthesis are available or are potentially available. In addition, well diversified experience and information obtained in the operation of water-gas plants and in gas purification gives the industry a particular advantage in the manufacture of synthesis gas for the Fischer-Tropsch process. Accordingly, the Institute of Gas Technology initiated a basic research project to study the utilization of carbon monoxide-hydrogen mixtures for the synthesis of valuable products.

THE Fischer-Tropsch synthesis or modifications thereof appears to have important implications for the gas industry:

***First*, it represents a means of upgrading gas;**

***Second*, a new use for gas is developed; and**

***Third*, the enrichment of water gas can be made independent of petroleum.**

The last item is important from the viewpoint of the industry as well as in the interests of obtaining complete national self-sufficiency in regard to liquid fuels.

This paper was presented before the Gas and Fuels Division of the annual meeting of the American Chemical Society, New York, September 11 to 15, 1944.

It is the purpose of this paper to trace the development of the Fischer-Tropsch synthesis, to point out the various difficulties and to discuss the possibilities of the process as a contribution of the gas industry to national welfare.

Historical Development of the Fischer-Tropsch Synthesis

The pioneering work in the production of hydrocarbons from water gas was that of Sabatier,[2] who found that finely divided nickel would catalyze the reduction of carbon monoxide to methane.

$$CO + 3H_2 \longrightarrow CH_4 + H_2O \quad (4)$$

There are four potential uses for this reaction namely: (a) enrichment of the heating value of water gas; (b) production of a substitute for natural gas; (c) standardization of the composition and heating value of gas throughout the country; and (d) purification of hydrogen for use in hydrogenation processes which employ catalysts susceptible to carbon-monoxide poisoning.

However, aside from the added expense involved and the loss of heat due to formation of water (equation 4), two major technical difficulties are encountered, namely, poisoning by sulfur and poison-

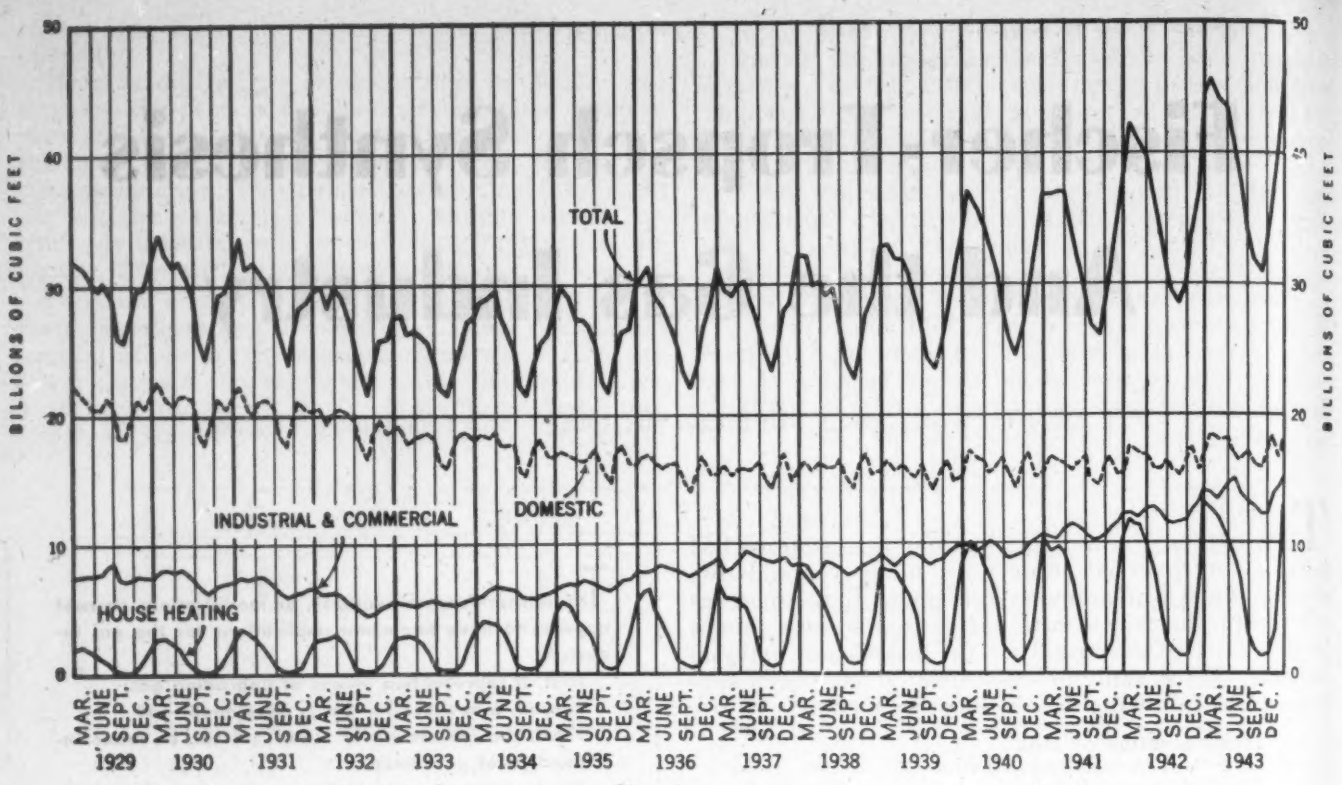
BILLIONS OF CUBIC FEET
TOTAL
INDUSTRIAL & COMMERCIAL
DOMESTIC
HOUSE HEATING
MAR. JUNE SEPT. DEC.
1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943

FIGURE 1
Monthly sales of manufactured gas

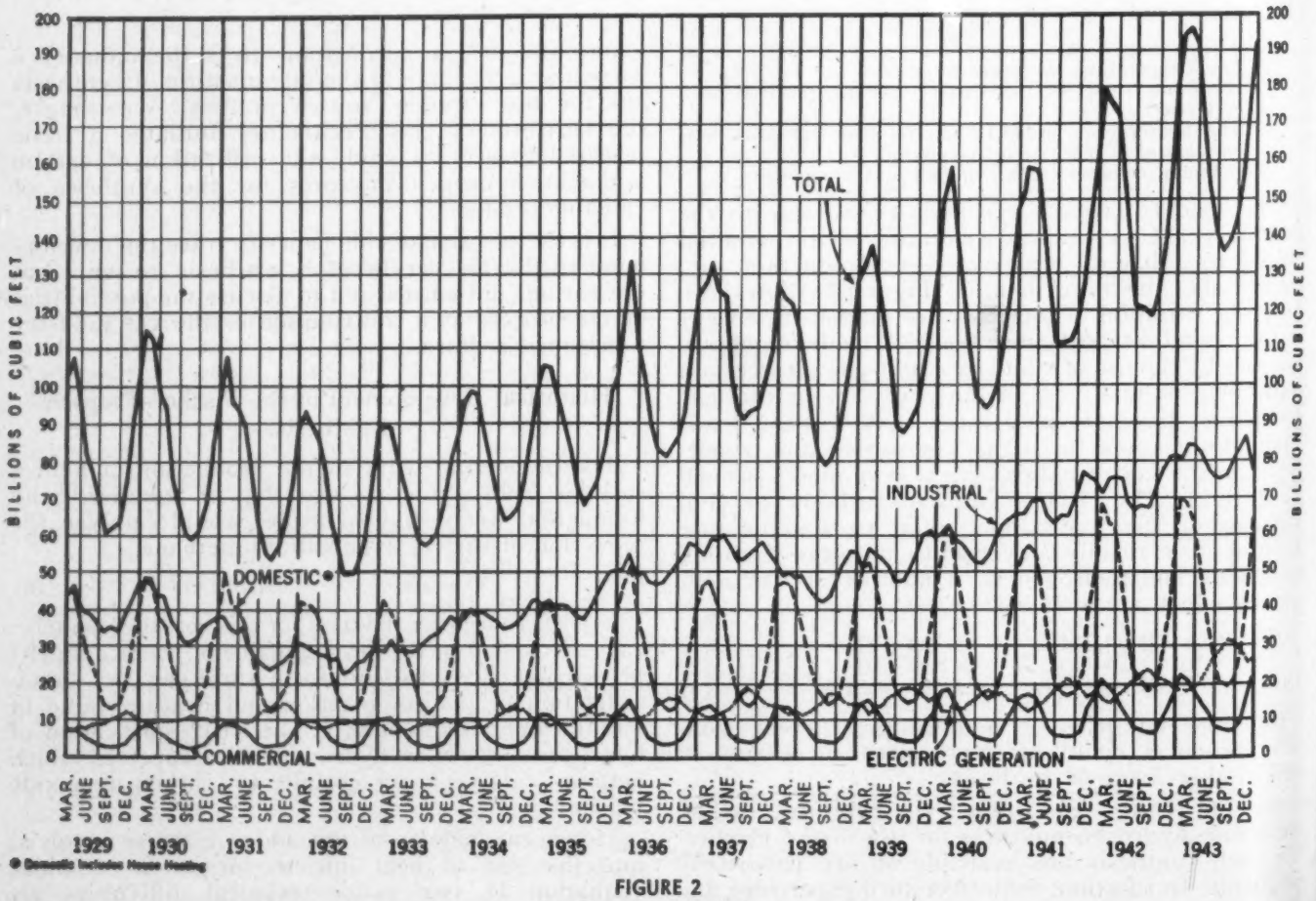

FIGURE 2
Monthly sales of natural gas

TABLE 1
Composition of Synthol

GROUP	Fraction of Total Product Percent	Identified	Approximate Fraction of Total Product Percent
Acids	10	Formic acid	0.1
		Acetic acid	2.3
		Propionic acid	2.1
		Isobutyric acid	1.0
		Higher acids (to C_8)	4.5
Water soluble alcohols—Aldehydes and ketones	29	Methyl alcohol	1.5
		Ethyl alcohol	14.5
		Propyl alcohol	....
		Acetone	5.2
		Methyl ethyl ketone	....
Partly miscible with water	11	....	....
Oil volatile with steam	48	Propionic aldehyde	....
		Isobutyric aldehyde	....
		Di-ethyl ketone	....
		Methyl-n-propyl ketone	....
		Higher alcohols (to C_9)	15.0
		Esters	2.0
		Hydrocarbons	1.0
Oil not volatile with steam	2	....	....

TABLE 2
Effect of Alkali Strength

Catalyst Composition (In order of increasing alkalinity)	Temp. °C	Pressure Atm.	Yield cc per cu. m.
Fe + LiOH	420	141–124	0.8
Fe + NaOH	420	141–121	10
Fe + KOH	420	140–130	40
Fe + RbOH	420	140–133	48

TABLE 3
Effect of H:CO Ratio

Ratio H : CO	Temp. °C.	Pressure Atm.	Yield* cc per cu. m.
2 : 1	410	122	17
1 : 1	410	72	26
1 : 2	410	95	32

* Includes estimated synthol content of the water layer.

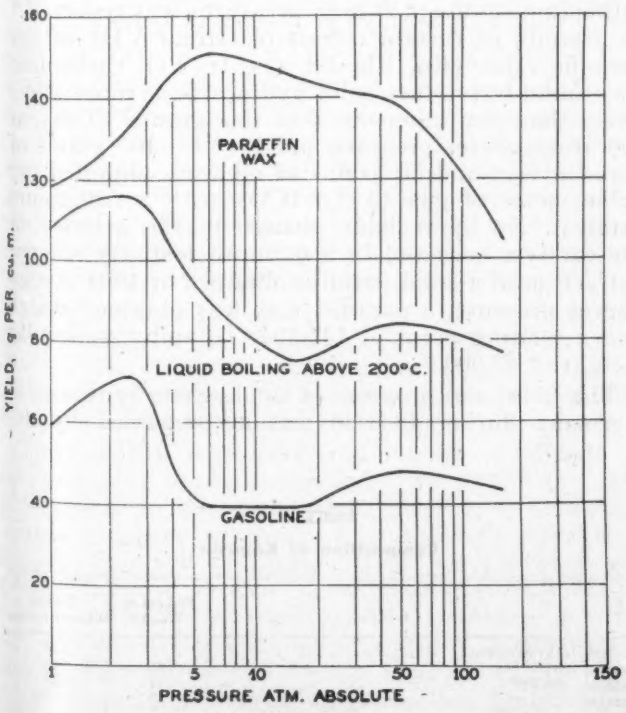

FIGURE 3
Effect of pressure upon yields of hydrocarbons (CO-ThO_2-Kieselguhr catalyst)

—Fischer-Tropsch Synthesis and the Gas Industry—

ing by carbon deposition. The latter is caused by a blanketing of the active catalyst centers according to the following reaction:

$$2\,CO \longrightarrow C + CO_2 \qquad (5)$$

The conditions favoring the production of methane rather than the Fischer-Tropsch synthesis of higher-molecular-weight hydrocarbons are: (i) catalyst; (ii) relatively high temperature; and (iii) high proportion of hydrogen in the reacting gases. Nickel and iron catalysts are active at atmospheric pressure. The temperature required is about 300° C. for nickel catalysts. The ratio of hydrogen to carbon monoxide theoretically should be three (equation 4).

It is of passing interest that carbon dioxide may be hydrogenated to methane at 300° C. over a pure iron catalyst.[3] Ruthenium powder or ruthenium-thoria-asbestos also may be used for the production of methane from CO_2 at 100° C.[4] However, after the initial step which is conversion to carbon monoxide and water vapor, the reduction proceeds according to equation (4).

In 1913 the Badische Anilin- und Sodafabrik[5] patented the conversion of mixtures of carbon monoxide and hydrogen into saturated and unsaturated gaseous and liquid hydrocarbons, alcohols, aldehydes, acids and ketones by catalytic treatment at elevated temperatures and pressures. Mixtures of two or more parts of carbon monoxide and one of hydrogen passed over a catalyst impregnated with alkali and oxides of cobalt, osmium or zinc, gave the above products at pressures of 100-120 atmospheres and temperatures of 300-400° C.

In 1923 Franz Fischer and Hans Tropsch reported the reduction of carbon monoxide in the presence of alkali-iron catalysts at 400-450° C. and 100-150 atmospheres pressure.[6] The product was a mixture of aliphatic alcohols, aldehydes, ketones, acids and esters which was given the name synthol.* Practically no hydrocarbons were found in this mixture (Table 1).[7] By heating synthol at 450° C. for one hour, a mixture of hydrocarbons was received.

Later work showed that the yield of oxygen-containing compounds increased with increasing strength of alkali incorporated in the catalyst[8] (Table 2) and with decreasing ratio of hydrogen to carbon monoxide[9] (Table 3).

By a reversal of the conditions for increasing synthol production (i.e., lower pressure, high hydrogen-to-carbon-monoxide ratio, no alkali in catalyst), Fischer and Tropsch in 1926 converted mixtures of carbon monoxide and hydrogen to a product almost free from oxygen-containing compounds.[10] Iron or cobalt catalysts were employed at atmospheric pressure and 250-300° C. The product, consisting largely

* Derived from the German: *synthetisches Öl.*

TABLE 4
Yields of Hydrocarbons at Different Pressures Over a a CO-ThO_2-kieselguhr catalyst

Yield*, Grams per cubic meter

Pressure Gage, Atm.	Total Solid and Liquid Hydrocarbons	Paraffin Wax	Oil Boiling (Above 200 °C.)	Gasoline Boiling (Below 200° C.)	Gaseous Hydrocarbons Including C_3 and C_4
0	117	10	38	69	38
1.5	131	15	43	73	50
5	150	60	51	39	33
15	145	70	36	39	33
50	138	54	37	47	21
150	104	27	34	43	31

* Yields are average of four weeks operation.

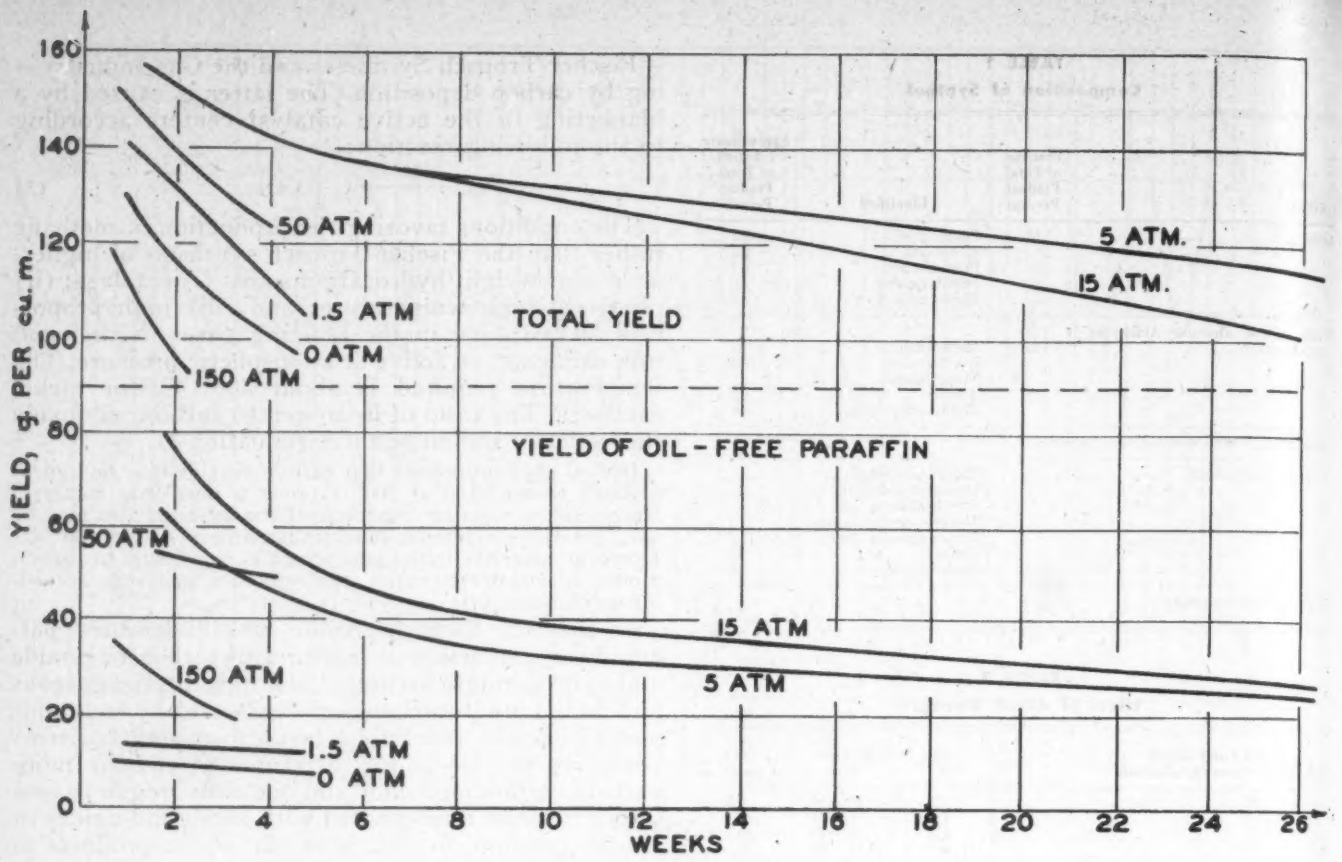

FIGURE 4

Effect of pressure on catalyst activity and life (CO-ThO_2-Kieselguhr catalyst)

of hydrocarbons ranging from ethane to solid paraffin wax, is known as kogasin.† The production of synthetic gasoline from water gas is known as the kogasin synthesis whereas Fischer-Tropsch synthesis is a more general term for the conversion of water gas to liquid products.

Later work (1932) showed that a nickel-manganese oxide-alumina-kieselguhr catalyst was superior to earlier cobalt catalysts for kogasin synthesis at "normal" or atmospheric pressure.[11]‡

By 1933 the kogasin process had been successfully developed on a laboratory and pilot-plant scale. As a result, Ruhrchemie A.G. was able to construct a plant of 1000 tons per year capacity at Oberhausen-Holten.[12] The synthesis gas (1 CO : $2H_2$), after removal of sulfur compounds (0.1 grain of sulfur per 100 cubic feet), was passed over a nickel-alumina-manganese dioxide-kieselguhr catalyst at 190-210° C. and atmospheric pressure. Industrial progress was rapid until at the end of 1936, there were five plants in Germany with a total capacity of about 805,000 barrels per year.[13]

The industrial progress of the kogasin synthesis was accelerated by the discovery of the "middle-pressure" synthesis by Fischer and Pichler in 1936.[14] At pressures of 5 to 15 atmospheres an optimum yield of solid plus liquid hydrocarbons was received (Table 4, Figure 3).[15] The chief advantage of this type of operation was that loss in catalyst activity was decreased. Whereas the yield dropped from 130 to 100 grams per cubic meter in "normal-pressure" (atmospheric) synthesis in 4 weeks, the "middle-pressure" synthesis produced 150 grams initially and still was above 100 grams per cubic meter after 26 weeks of operation (Figure 4). This synthesis has been performed with cobalt[14] and iron (1937)[16] catalysts; nickel catalysts deteriorate rapidly due to formation of nickel carbonyl at these pressures.

In 1938 the synthesis of high-melting wax on ruthenium catalysts at high pressures was reported.[16] In a study of certain metals of Group VIII of the periodic table (Ru, Rh, Pd, Os, Ir, Pt), ruthenium was found to produce solid hydrocarbons more effectively than any other metal of this group.[17] Thus, at 100 atmospheres pressure and 195° C., 100 grams of paraffin wax and 50 grams of oil were obtained per cubic meter of gas ($2H_2$: 1CO) with a ruthenium catalyst. No appreciable change in the activity of the catalyst occurred in a 6-month test. By solvent extraction of a solid paraffin obtained at 1000 atmospheres pressure, a paraffin wax was obtained which had a melting point of 132-134° C. and a molecular weight of 23,000.[18]

The industrial progress of the kogasin synthesis in Germany during 1933-40 was accompanied by de-

TABLE 5

Composition of Kogasin

	Percent by Weight	Olefins, Volume Percent
C_3- and C_4- hydrocarbons	8	55
Gasoline (to 150° C.)	46	45
Naphtha (150-200° C.)	14	25
Diesel oil	22	10
Paraffin wax from oil*	7	..
Paraffin wax from catalyst†	3	..

* Melting point, 50° C. † Melting point, 90° C.

† A contraction of the German: *Kohle-Gas-Benzine.*

‡ Later developments show that a cobalt-thoria-kieselguhr (100:18:100) catalyst is the best catalyst for Kogasin synthesis. This catalyst is active at 175° C. and optimum activity is obtained at temperatures of 190-200° C.

TABLE 6

Processing of Kogasin to Produce Gasoline

	Yield, Volume-Percent*
Light gasoline†	29.1
Reformed gasoline from naphtha‡	26.8
Cracked gasoline from bottoms	22.6
Polymer gasoline	5.8
	84.3
Octane number of blend of all gasolines, 66	

*Based on Kogasin oil charged; original octane number was 20.
†Octane number of 36-116° C. fractions was 68.
‡Octane number of the 104-273° C. fraction before reforming was 4.

synthetic lubricating oils. Among those which have been reported are: (1) polymerization of fractions rich in olefins with aluminum chloride;[24] (2) chlorination of a kogasin fraction and polymerization without the addition of aromatics,[25] and (3) alkylation of aromatic hydrocarbons with chlorinated fractions, according to the Friedel-Crafts reaction.[26] Excellent viscosity properties (as shown by viscosity index of 90-100) are reported for these synthetic lubricating oils.[27]

From the above historical development of the Fischer-Tropsch process, it may be seen that much

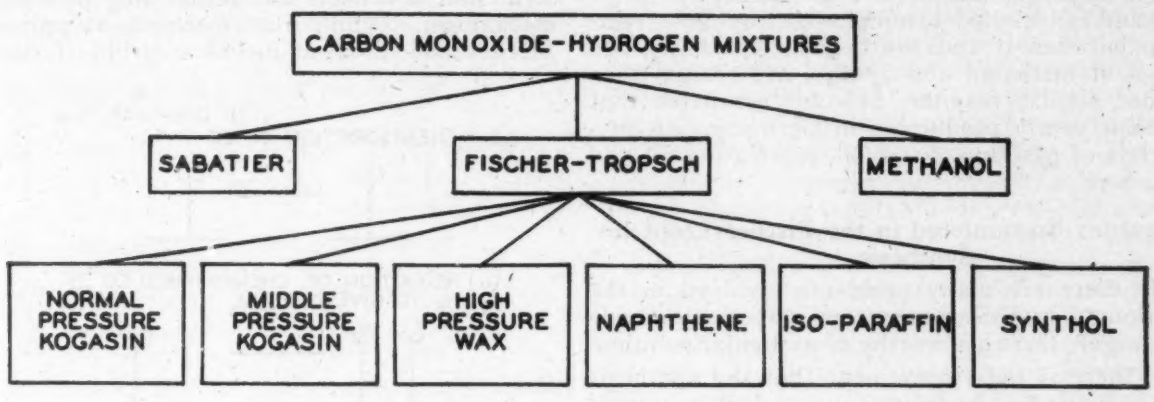

FIGURE 5

Major developments of the Fischer-Tropsch synthesis and related processes

velopments in the utilization of the reaction products. The primary product is composed of largely straight-chain paraffin and olefin hydrocarbons with only minor amounts of aromatics, naphthene hydrocarbons or oxygen-containing compounds. Table 5 presents data for the various fractions of the primary product when a cobalt catalyst was used.[19] The gasoline boiling up to 200° C. constitutes 60 percent of the total product. Because of the straight-chain nature of the hydrocarbons in the product, the gasoline fractions have low octane numbers. Thus, the octane number of the gasoline boiling in the aviation range (up to 150° C.) was only 55.

The octane number of the gasoline and the total yield of gasoline can be increased by reforming and cracking in conventional petroleum-plant equipment. Thus, Egloff, Nelson and Morrell,[20] by means of thermal reforming and cracking and catalytic polymerization of the cracking gases, received 84.3 percent of 66-octane gasoline from a kogasin oil which originally had an octane number of 20 (Table 6).

Diesel oil may be separated from the total kogasin oil by simple distillation. It has a high cetane number due to the straight-chain character of the hydrocarbons contained in this fraction and is suitable for mixing with low-cetane-number oils.[21]

The paraffin wax produced in the synthesis is similar to the product received from petroleum and can be put to the same uses. Since 1936 catalytic oxidation of the synthetic wax has been used for the production of synthetic fatty acids. The product consists almost entirely of saturated normal fatty acids of both odd and even carbon number,[22] which are used for the manufacture of soap, cooking fats and artificial butter.[23]

The kogasin product as such does not contain any lubricating oils. To meet this need, methods have been developed in Fischer's laboratory to produce

work has been done by the Germans, particularly in Fischer's laboratory. This was due, in part, to the desire of Germany to obtain self-sufficiency in regard to petroleum products. However, many contributions to the synthesis have come from other countries. In Great Britain an experimental plant of 150 gallons per day has been erected to test the Robinson-Bindley process,[28] a smaller plant (4 gallons per day) has also been constructed by the Fuel Research Board.[29] The chief advantage of the Robinson-Bindley process is that it utilizes smaller hydrogen-to-carbon-monoxide ratios than the Fischer-Tropsch synthesis.

In Japan much work has been done by investigators there although no outstanding development has been disclosed.

In the United States, work has been done as early as 1928[30, 31] on the Fischer-Tropsch process. Smith, Hawk and Golden[32] found that the addition of ethylene to the synthesis gases produced large quantities of higher hydrocarbons and oxygen-containing compounds. This was an important discovery since it may help to clarify the reaction mechanism. The reaction will be discussed more fully under "Mechanism of the Reaction."

Recent Developments

Since the start of World War II, two new syntheses have been announced, "naphthene synthesis" and "iso-synthesis."[16] Naturally details have not been disclosed. Both of these discoveries are due to the direction of the reaction toward the production of a specific class of hydrocarbons, e.g., in the naphthene synthesis, naphthenes and aromatics are produced. As noted above, only saturated and unsaturated straight-chain hydrocarbons are synthesized in the kogasin synthesis. In the production of aviation gasoline, this is a serious objection because of the low octane number of the product. However, by means

of the "iso-synthesis," it is implied that iso-paraffins are produced directly and that the gasoline fractions would have high octane numbers. The C_4-fraction from the process contains 90 percent of iso-butane.[16] This, in itself, is important since by converting half of the iso-butane to iso-butene (by dehydrogenation) and alkylation of the remaining iso-butane with the iso-butene produced, 100-octane aviation gasoline could be produced.

The major developments of the Fischer-Tropsch synthesis and two allied processes are shown in Figure 5 to summarize the main uses of carbon monoxide-hydrogen mixtures. The Sabatier synthesis of methane is included to emphasize the close relationship between it and the kogasin synthesis, the synthesis of methanol and synthol are related in a somewhat similar manner. Storch[13] estimates that the present yearly production in Germany is 5,590,000 barrels of gasoline, diesel oil, lubricating oil and paraffin wax.

Difficulties Encountered in the Fischer-Tropsch Synthesis

While there are many problems involved in the production of hydrocarbons from carbon monoxide and hydrogen, three are worthy of particular mention.

First, there is the requirement that the synthesis gas be composed of hydrogen and carbon monoxide in the ratio of 2:1 for the industrially developed cobalt catalysts. This is occasioned by the nature of the reaction, i.e.,

$$nCO + 2nH_2 \longrightarrow (CH_2)n + nH_2O \qquad (6)$$

Since conventional water-gas sets produce a gas containing only slightly more hydrogen than carbon monoxide, additional hydrogen must be obtained from some source. Known methods of producing hydrogen, such as the catalytic reaction of steam with carbon monoxide or low-temperature fractionation of coke-oven gas, may be employed. The direct production of synthesis gas from various materials has been reviewed.[33]

A second problem is the removal of the heat of reaction. With cobalt or nickel catalysts the reaction is normally,

$$CO + 2H_2 \longrightarrow (CH_2) + H_2O + 44\ \text{k-cal} \qquad (7)$$

while for iron catalysts, the reaction is,

$$2CO + H_2 \longrightarrow (CH_2) + CO_2 + 43.7\ \text{k-cal} \qquad (8)$$

Since the reaction is very sensitive to temperature, the optimum temperature must be rigidly maintained within 5-10° C. throughout all parts of the catalyst zone. These difficulties have been largely overcome by proper reactor design.

The third difficulty, which has proved a considerable obstacle to the progress of the synthesis, is the necessity for removing almost all the sulfur from the synthesis gas. The upper limit of sulfur concentration which can be tolerated by the active catalysts is approximately 0.1 grain per 100 cubic feet. The problem can be solved in one of two ways: (a) by means of desulfurization or (b) by developing a sulfur-resistant catalyst. Up to the present the first method has been used almost exclusively since a sufficiently active sulfur-resistant catalyst has not yet been developed.

Mechanism of the Reaction

Fischer and Tropsch[10] proposed that the first step in the synthesis was the formation of carbides with the metal of the catalyst. The second step was the reduction by hydrogen of the carbide to form methylene radicals. The final step was the polymerization of the radicals to form hydrocarbons other than methane.

Since carbide formation on the catalyst has been always associated with the production of liquid hydrocarbons,[34] it seems logical that any mechanism proposed must take this fact into acount. Thus, reduction of Fischer-Tropsch carbides with hydrogen as well as acid decomposition leads to higher hydrocarbon formation. Hence, it seems likely that carbide formation is a necessary initial step in the reaction mechanism. While the mechanism proposed by Fischer and Tropsch includes carbide formation, it

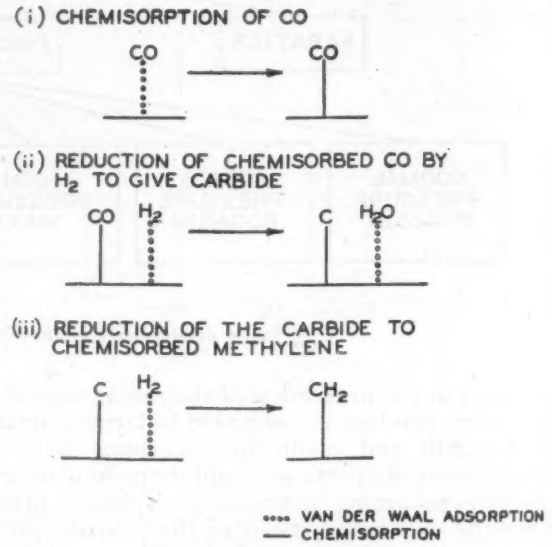

FIGURE 6
Mechanism of the synthesis of hydrocarbons (Craxford)

fails to explain adequately some of the other features of the reaction.

Craxford[35, 36] has developed a mechanism which is satisfactory in many respects. The first step is the reaction of both carbon monoxide and hydrogen to form carbide.

$$2Co + CO + H_2 \longrightarrow CO_2C + H_2O \qquad (9)$$

This reaction is faster than the reduction of carbide by hydrogen under the synthesis conditions (Steps i and ii, Figure 6). Therefore, carbides can be built up on the catalyst during the early stages of synthesis. In the next step, the carbide is reduced by molecular hydrogen to form a surface methylene (Step iii). Craxford found a parallelism between ortho-para hydrogen conversion and methane formation in all cases investigated. Thus, when methane was the main product of the hydrocarbon synthesis, the ortho-para hydrocarbon conversion was high, an indication of the presence of chemisorbed hydrogen. Alternately, if the catalyst was producing liquid hydrocarbons, the ortho-para hydrogen conversion was inhibited, or very little chemisorbed hydrogen was present on the catalyst surface. Therefore, it is postulated that in the presence of a large amount of chemisorbed hydrogen, methane is evolved from the reaction (Step iv a, Figure 7). In the presence of smaller amounts of chemisorbed hydrogen, it is postulated that reduc-

tion of the carbide occurs with molecular hydrogen to produce liquid hydrocarbon.

$$nCo_2C + nH_2 \longrightarrow (CH_2)n + 2nCo \qquad (10)$$

This step may take place through the formation of macro-molecules on the catalyst surface (Step iv b, Figure 7). The release of paraffin or olefin hydrocarbons depends upon the prevailing synthesis conditions, i.e., hydrogen-carbon monoxide ratio, catalyst, temperature and pressure. While the Craxford mechanism is valuable, it is, nevertheless, complicated and, so far, limited to cobalt catalysts.

Basing their conclusions on experimental observations with cobalt catalysts, Herington and Wood-

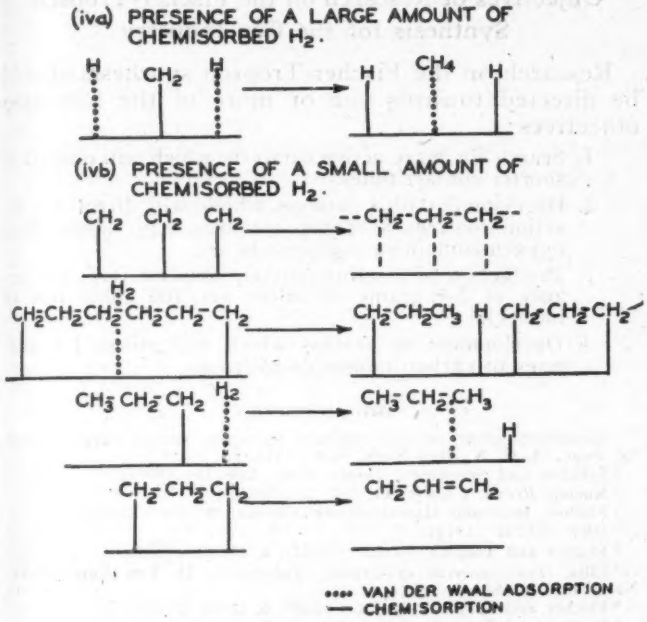
(iva) PRESENCE OF A LARGE AMOUNT OF CHEMISORBED H_2.
(ivb) PRESENCE OF A SMALL AMOUNT OF CHEMISORBED H_2.
•••• VAN DER WAAL ADSORPTION
— CHEMISORPTION

FIGURE 7
Mechanism of the synthesis of hydrocarbons (Craxford)

ward[37] take the view that a cobalt catalyst possesses active centers of two types: Type A (probably cobalt carbide) which is responsible for the formation and polymerization of methylene groups; and Type B (probably cobalt metal) which causes liberation of the products observed. When Type B centers predominate, only gaseous products are formed; when Type A centers predominate, liquid products are formed. This mechanism is simpler than the Craxford mechanism but also is limited in application to cobalt catalysts.

It is our suggestion that the catalyst surface and, more particularly the composition of the catalyst has a large influence on the reaction mechanism. Thus, it seems evident in a broad sense that on the catalyst surface, two separate influences are present,

a. Hydrogenating effect
b. Polymerizating effect

Thus, carbon monoxide molecules are reduced to methylene groups which, in turn, are polymerized to higher hydrocarbons. The initial step in the reaction is the formation of carbide with the metal of the catalyst surface. This step requires that the catalyst contain a metal which is capable of forming a carbide. The second step is the reduction of carbide on the catalyst surface: hence, a hydrogenating catalyst is required. Finally, the third step involves the polymerization of the methylene groups and indicates that the presence of a polymerizing catalyst would be advantageous. Consequently, the catalyst must comply with the following conditions.

1. Ability to form a carbide from carbon monoxide
2. Hydrogenating ability
3. Polymerizing ability

Certain metals of the 8th group, i.e., nickel, cobalt and iron, fulfill the requirement of forming carbides of suitable stability. These metals also possess hydrogenating ability and thus satisfy condition 2. However, if pure nickel, for example, is used, only methane is formed and hydropolymerization to produce liquid products does not occur. Therefore, the hydrogenating effect must be decreased by supporting nickel on a carrier (kieselguhr) and polymerization reactions enhanced by the addition of other ingredients in order to produce higher hydrocarbons.

While under certain conditions a catalyst composed of one element would fulfill all three of the postulated requirements, practically, a multi-component or "complex-action" catalyst[38] is required. The idea of "complex-action" catalysts is not new and has been used to describe the action of certain catalysts which produced, for example, hydropolymerization of isobutene to iso-octane[39] and dehydropolymerization of ethylene.[40] If it is accepted that the Fischer-Tropsch reaction occurs through the use of a "complex-action" catalyst it narrows the selection of catalysts to *direct* the Fischer-Tropsch synthesis into producing hydrocarbons of desired size and structure.

Many of the phenomena observed during the reaction can be explained on the basis outlined. Thus, the necessity for complete sulfur removal may be caused by the fact that the hydrogenating portion of the catalyst is readily poisoned by sulfur, thereby stopping the initial reduction of carbide. However, Herington and Woodward[37] found that the initial effect of adding hydrogen sulfide to the synthesis gas was to increase the yield of heavier oils while the production of lighter hydrocarbons diminished. The total effect for small quantities of sulfur may be an increase in yield as reported by other workers.[41] Since the polymerizing active centers would be relatively unaffected while the hydrogenating centers were poisoned by sulfur, it might be expected that, initially, the yield of heavier oils might increase at the expense of the lighter hydrocarbon yield. Eventually, sufficient sulfur can be added to destroy completely the hydrogenating influence of the catalyst and thereby stop all reaction.

Fischer and Pichler[15] attribute the increased time of high catalyst activity in the "middle pressure" synthesis to the fact that certain poisons, perhaps oxygen-containing compounds are hydrogenated and rendered inoccuous under these conditions (5-15 atmospheres). This speculation may be correct. However, whether the poisoning is due to certain oxygen compounds or not, it should be pointed out that, in general, increased pressure reduces the sensitivity of hydrogenation catalysts to poisoning. Therefore, it might be anticipated that in the synthesis of hydrocarbons over a hydrogenation-polymerization catalyst, susceptibility to poisoning of the hydrogenating portion would be reduced at higher pressures and would lead to long periods of high catalyst activity.

Smith, Hawk and Golden[32] found that when ethylene was added to the synthesis gas, large quantities of higher hydrocarbons and oxygen-containing

compounds were formed over a cobalt-base catalyst. These facts are explainable by noting that while the relationship between the hydrogenating and polymerizing portions of the catalyst remained constant, ethylene, being strongly adsorbed and highly reactive, combined with methylene on the catalyst surface as well as reacted with carbon monoxide (under the influence of the polymerizing portion of the catalyst). The hydrogenating influence remained constant and had a smaller influence on the nature of products. Ethylene alone or in admixture with either carbon monoxide or hydrogen did not form higher hydrocarbons under the same conditions. With an iron-base catalyst, ethylene did not give the same reaction. It may be possible that ethylene is not sufficiently adsorbed on this patricular catalyst.

In general the mechanism of the reaction over an iron catalyst appears to be quite different than that over cobalt or nickel catalysts. Storch[42] has enumerated and discussed these facts recently. While the published work on iron catalysts is rather incomplete, it is believed that the "complex-action" idea can be applied advantageously in this instance also.

In summary, recognition of the necessity of finding a "complex-action" catalyst which combines both hydrogenating and polymerizing properties should narrow the search for catalysts which direct the Fischer-Tropsch synthesis into specific desirable reaction products.

Utilization of the Fischer-Tropsch Synthesis in the Gas Industry

Manufactured-Gas Plants. In the manufactured-gas industry the main potential use of the Fischer-Tropsch synthesis is to utilize water-gas sets during off-peak gas production. It is obvious that the investment cost should not be much greater than that of the water-gas plant. In the interests of distribution the product preferably should be either gaseous or readily gasified. The production of condensable gaseous hydrocarbons (C_3 and C_4) is suitable because these are readily stored and can be used to enrich the gas and to supplement peak loads. The liquid products are particularly suited to water-gas enrichment because of the paraffinic nature of the product. A possible means of utilizing the Fischer-Tropsch process is the production of valuable materials. Such production may or may not be conducted by the gas companies. Materials which can be produced include iso-butane, iso-butene and other butenes, iso-paraffins, high melting wax and oxygen-containing compounds.

The production of gasoline from coal or coke by the kogasin process is not contemplated by the gas industry. While the production of Fischer-Tropsch gasoline does not seem economic at present* future developments may change this particularly if high-octane aviation gasoline could be produced directly.

Natural Gas. The considerations outlined above hold true for the natural-gas industry also. The low load factor for natural gas could be improved by utilizing the Fischer-Tropsch process during the off-peak season, to make new products as outlined above. The cost of production, however, might be lower due to the present low price of natural gas.† It is conceivable that natural gas could be converted to gasoline by the kogasin process in competition with petroleum in certain favorable localities. However, the Fischer-Tropsch synthesis should be directed preferably towards the preparation of more valuable products, e.g., the production of iso-paraffins or oxygen-containing compounds.

Objectives of Research on the Fischer-Tropsch Synthesis for the Gas Industry

Research on the Fischer-Tropsch synthesis should be directed towards one or more of the following objectives:

1. Search for more active catalysts which will operate at shorter contact times.
2. Development of a catalyst which will direct the reaction towards a specific product, e.g. iso-paraffins, oxygen-containing compounds, etc.
3. Production of a sulfur-resistant catalyst (e.g., a tolerance of 2-4 grains of sulfur per 100 cubic feet or higher).
4. Development of process which will utilize 1:1 mixtures of carbon monoxide-hydrogen.

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* Wilson[43] estimates about 5 cents per gallon above present price from petroleum.

† With natural gas at 5 cents per thousand cubic feet, Russell[44] estimates a cost of 3.3 cents per gallon and predicts 4.3 cents after development. In a modern oil refinery, with crude at $1.20 per barrel, the cost of gasoline from petroleum is 5.3 cents per gallon; if crude is $2.00 per barrel, the cost rises to 8.5 cents per gallon.

COMMERCIAL

Isomerization of Light Paraffins

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FIVE commercial plants are described in which normal butane, normal pentane and normal and slightly branched hexanes are converted to iso-compounds for aviation-gasoline manufacture. Feed stock mixed with anhydrous HCl is passed upward in small liquid drops through a liquid aluminum chloride-hydrocarbon complex catalyst. Fairly pure neohexane can be made by fractionation and recycling the remaining hexanes. Hexanes and pentanes may be isomerized together. Very high liquid yields are obtained.

This paper was presented before the Division of Petroleum Chemistry at the meeting of the American Chemical Society, New York, September 11-15, and printed in the News Edition of *Industrial and Engineering Chemistry*, November 10, 1944.

STANDARD Oil Company (Indiana) and subsidiaries are putting five new plants into operation at their refineries for the production of isobutane and aviation gasoline components by the isomerization of light paraffinic hydrocarbons. These plants, listed below, employ three separate new processes for the isomerization of light naphtha, pentane and butane, all of which are integrated with the current 100-octane-number aviation gasoline production at these refineries.

COMPANY	Refinery Location	Type	Reactor Charge Barrels Per Day
Standard Oil Co., (Indiana)	Whiting	Isomate	5,000
Standard Oil Co., (Indiana)	Whiting	Isobutane	4,530
Utah Oil Refining Co.	Salt Lake City	Neohexane	1,750
Standard Oil Co., (Indiana)	Wood River	Isobutane	4,250
Pan American Refining Corporation	Texas City	Isopentane	1,620

While new aviation-gasoline plants are starting up nearly every day, the number of processes involved are relatively few. Therefore, it is felt that the novel character of the isomerization processes employed in the above plants warrants such description as secrecy orders, censorship, and regulations will permit.

The development of new catalytic isomerization techniques has not only made possible a simple continuous butane-isomerization process but, with the development of suitable inhibitors, has also furnished a simple pentane isomerization process and made possible the commercial production of neohexane and high-octane-number aviation blending stocks. The latter process greatly extends the potential source of aviation blending stocks in that light fractions of crude of low octane number, which cannot be readily processed to aviation gasoline quality by other methods, are converted in high yield to high-octane-number aviation gasoline components. The processes also have potentialities for producing aviation gasoline of higher quality than is now being made.

TABLE 1
Physical Properties of Pentanes and Hexanes

	B.P. °F.	R.V.P. Lb./Sq. In.	OCTANE NUMBER A.S.T.M. (Clear)	OCTANE NUMBER AFD 1-C+ 4.0 cc. TEL
Pentanes:				
Isopentane	82	21.0	90	100 + 1.9
n-Pentane	97	15.5	62	87
Hexanes:				
Neohexane	122	9.4	94	100 + 5.6
2, 3-Dimethylbutane	136	7.1	94	100 + 3.6
2-Methylpentane	141	6.5	74	96
3-Methylpentane	146	5.8	74	96
n-Hexane	156	5.0	26	69

General Description of Isomerization Processes

The effect of the structural arrangement of pentanes and hexanes on boiling point, Reid vapor pressure and octane number is shown in Table 1. From this table it is clear that the commercial importance of isomerization results from converting the straight or slightly branched hydrocarbons of poor octane number which predominate in crude to more highly branched isomers of high octane number.

In these processes, a paraffinic feed is contacted in a simple reactor with a liquid aluminum-chloride-hydrocarbon-complex catalyst in the presence of hydrogen chloride to yield a product rich in branched-chain aliphatic hydrocarbons. The catalyst is a dark mobile liquid with a specific gravity of about 1.5 and a viscosity slightly higher than SAE 50 lubricating oil. The reactor feed enters the bottom of the reactor as a liquid and undergoes isomerization as it passes upward in contact with the liquid catalyst. In spite of the fact that $AlCl_3$ is appreciably soluble in hydrocarbons this catalyst complex is substantially insoluble in hydrocarbons and may be readily separated therefrom by settling. Furthermore, the particular catalyst complex used has remarkable capacity for retaining $AlCl_3$ added as make-up due to the high $AlCl_3$ distribution coefficient between the complex and hydrocarbon at reactor conditions. This fact has made possible the important improvement of operat-

TABLE 2

Experimental Liquid Phase Equilibrium Distribution of Butanes, Pentanes, and Hexanes

	LIQUID VOLUME PERCENT			
Temperature	70° F.	212° F.	300° F.	400° F.
Butanes:				
Isobutane	85	75	65	57
n-Butane	15	25	35	43
Pentanes:				
Isopentane	95	85	78	71
n-Pentane	5	15	22	29
Hexanes:				
Neohexane	57	38	28	21
2, 3-Dimethylbutane	11	10	9	9
2-Methylpentane	20	28	34	36
3-Methylpentane	8	13	15	17
n-Hexane	4	11	14	17

ing in the liquid phase and on a continuous basis without excessive loss of catalyst.

Side reactions that decrease the yield of desirable products and increase catalyst requirements are minimized by the use of suitable inhibitors. The necessity of using such inhibitors depends on the type of charging stock employed and, in some cases, combinations of inhibitors give better results than any single inhibitor.

The character of the isomerization product is also determined to a considerable extent by the operating conditions and is limited by the chemical equilibrium. Table 2 presents the liquid-phase equilibria for butanes, pentanes and hexanes at various temperatures, as determined by laboratory experiments. Although there is substantial agreement in most instances with the theoretical values of Rossini, Prosen and Pitzer (J. Research Natl. Bur. Standards, **27**, 529, 1941), the experimental value for neohexane is somewhat lower and that for isobutane somewhat higher than the calculated. The only notable discrepancy is the complete absence of neopentane although thermodynamically it is the favored isomer at low temperature.

On the basis of these developments and the use of conventional fractionation systems and recycle, a complete system of isomerization for C_4, C_5 and C_6 paraffin hydrocarbons has been worked out. These isomerization processes may be classified as follows:

1—Naphtha Isomerization (Pentanes and Hexanes)
(a) Isomate (Once-through)
(b) Neohexane (Recycle)
2—Pentane Isomerization
3—Butane Isomerization

These processes, their variations and applications are described in more detail in the following paragraphs.

Naphtha Isomerization

The Indiana Naphtha Isomerization Process is particularly suited for the isomerization of hexanes; however, it is usually more desirable to process a light naphtha containing both pentanes and hexanes. The process may be employed on a once-through basis in which event the product constitutes a high quality aviation base stock containing the hydrocarbon components nearly in their equilibrium proportions. Alternatively, it may be operated on a recycle basis in which case the higher boiling, low-octane-number isomers may be selectively removed from the product by fractionation, and recycled to the reactor for further conversion. By this latter operation a product consisting predominantly of isopentane and neohexane may be produced. There are various other combinations such as recycle of n-pentane and once-through on hexanes or once-through on pentanes and recycle of hexanes which serve to illustrate the extreme flexibility of the processes. The reactor effluent from naphtha isomerization has been termed "isomate" and will be referred to as such hereafter.

Whiting Isomate Plant

The first of the Indiana isomerization processes to be placed in operation was the Whiting Isomate plant. This unit, charging 5000 barrels a day of light naphtha, isomerizes hexanes and pentanes simultaneously, operating once-through on hexanes and recycling on pentane. A simplified flow diagram showing the principal features of the unit is given in Figure 1.

A dry, light virgin naphtha fraction of approximately 160° F. ASTM end point, anhydrous hydrogen chloride and aluminum chloride are charged to the reactor system and spent catalyst is withdrawn.

The effluent from the reactor system is cooled in an aftercooler and enters a cold settler or receiver. This settler operates as a vapor release drum as well as a settler for any catalyst carried with the reactor effluent. The product from the cold settler passes to the HCl stripper, where HCl is taken overhead along with a small amount of light hydrocarbon gases. The overhead gases from the HCl stripper and make-up HCl are returned to the reactor system. A remarkably small amount of dry gas is formed in the isomerization process so that HCl losses due to venting are very low. The bottoms from the HCl stripper are caustic-and-water-washed to prevent traces of HCl from entering the fractionation system.

Fractionation System

The fractionation system is of the conventional type. The HCl-free isomerized product is debutanized and the butanes, consisting of 75 percent isobutane, are taken overhead. The bottoms flow to the depentanizer tower where pentanes are taken overhead and highly isomerized hexanes are withdrawn as bottoms. The pentane overhead, consisting of 75 percent isopentane, is further fractionated in the isopentane tower to produce isopentane of 95 percent purity and a recycle n-pentane stream for further conversion to isopentane. The isopentane and isomerized hexanes form a balanced high-octane-number light-base stock which materially increases the production of 100-octane-number aviation gasoline.

As shown in Table 3 the yield of debutanized isomate is extremely high, exceeding 95 percent by volume. The gaseous products are mainly isobutane which is a valuable by-product. When butanes produced are included with the liquid isomate the yield exceeds 100 percent by volume.

As pointed out before, the quality of the isomate is

TABLE 3

Yields and Product Quality for Once-Through and Recycle Hexane Isomerization

			RECYCLE RATIO	
	Hexane Feed	Once-Through	1:1 (Calculated)	2:1 (Calculated)
Yields:				
Dry Gas, Volume Percent	...	1.8	3.6	5.3
Butane, Volume Percent	....	3.8	6.3	8.7
Products, Volume Percent	....	96.8	87.2	85.2
Bottoms, Volume Percent	....	....	7.0	6.2
Product Octane Number:				
A.S.T.M. (Clear)	65.0	80.0	88.0	91.4
AFD 1-C+ 4.0 cc. TEL	87.0	100	100 + 1.5	100 + 3.6

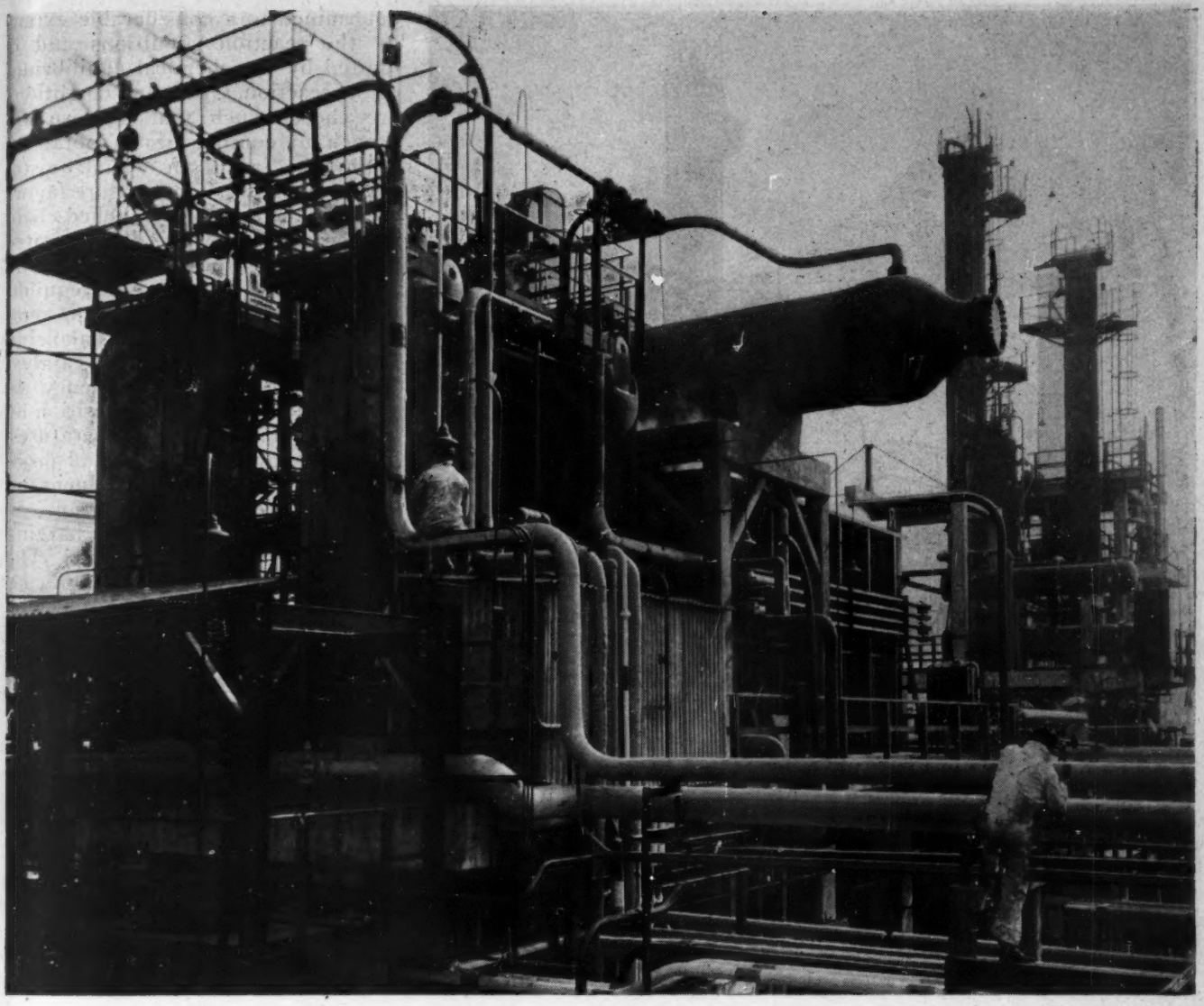
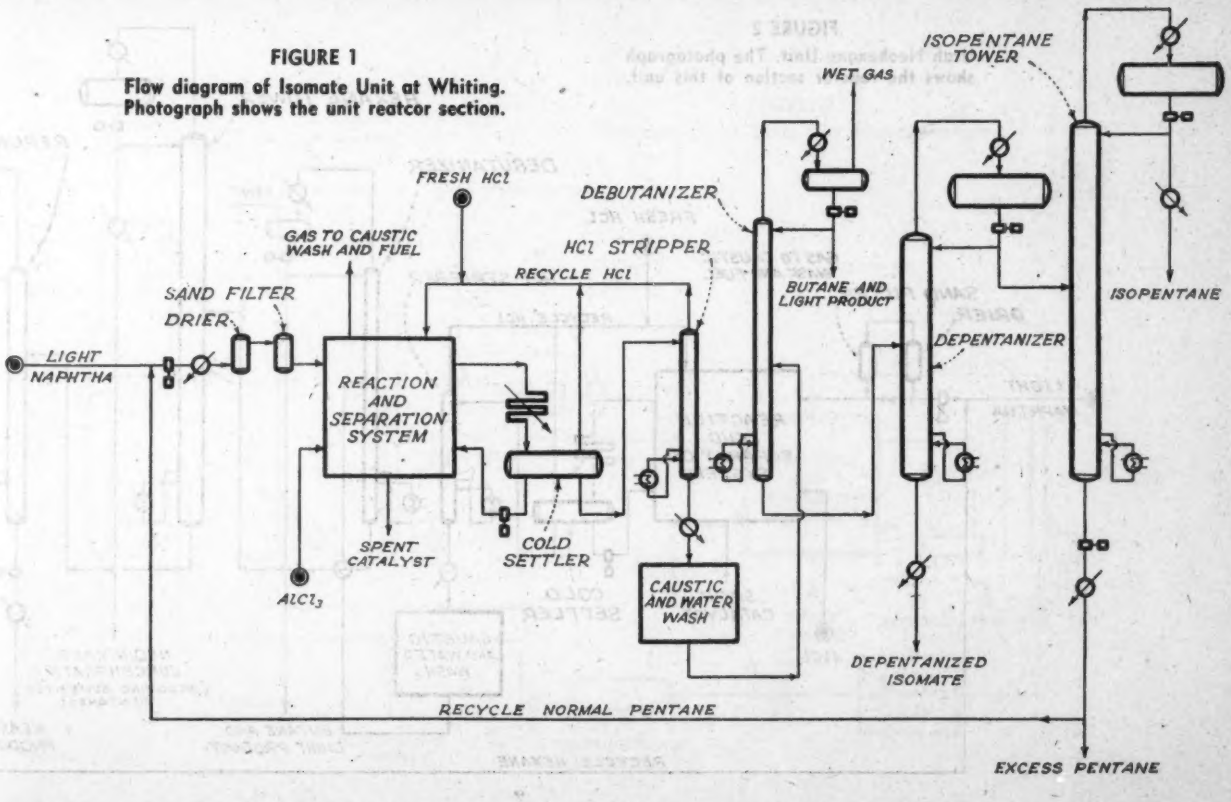
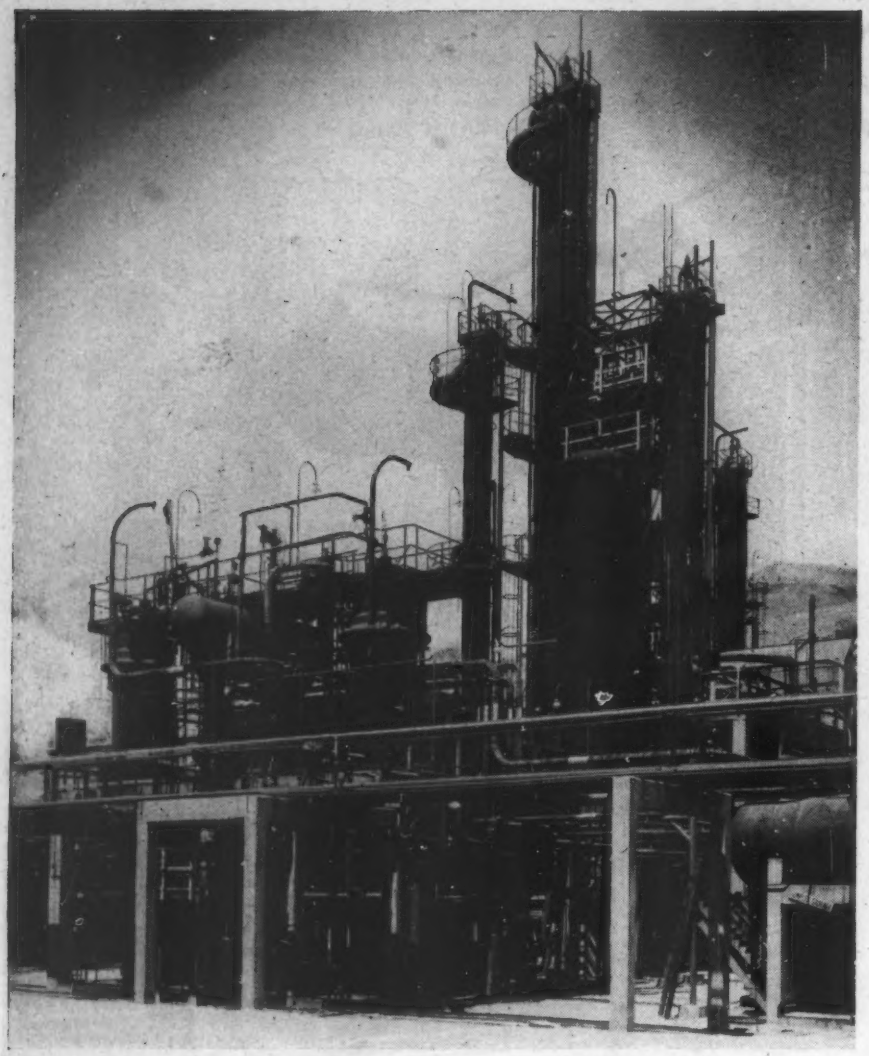


FIGURE 1
Flow diagram of Isomate Unit at Whiting. Photograph shows the unit reatcor section.





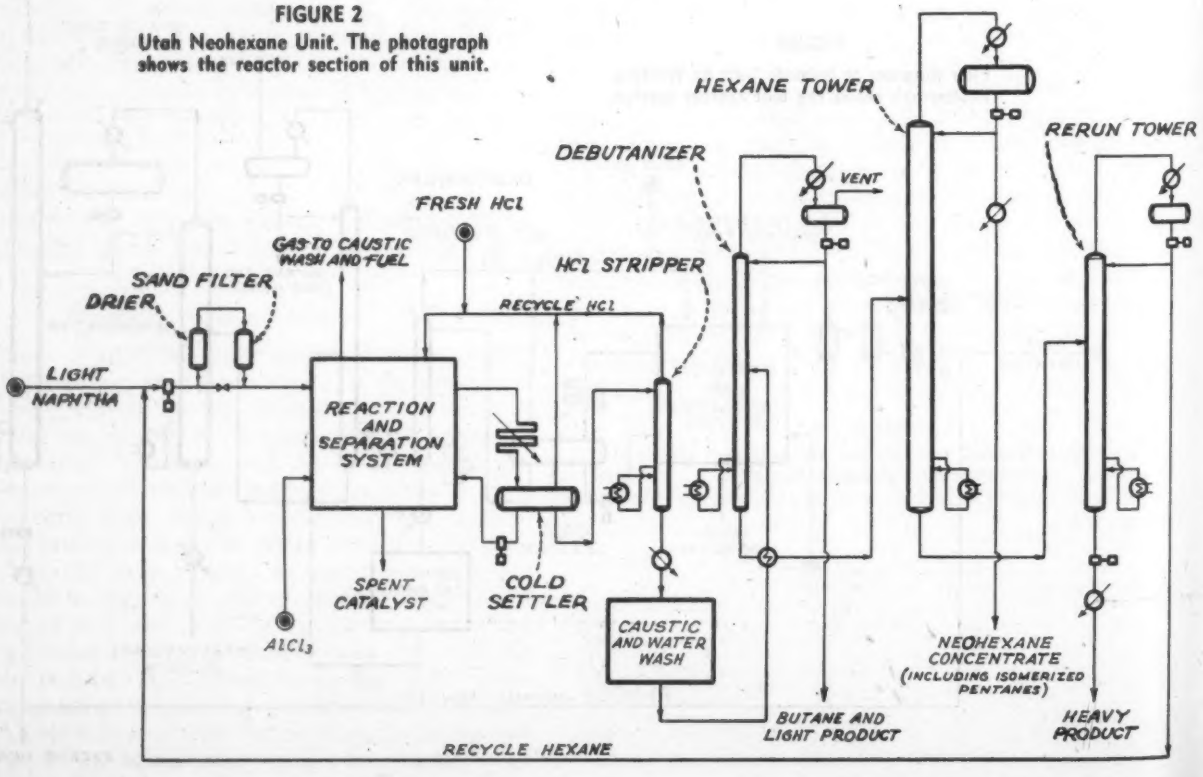
determined to a considerable extent by the reaction conditions and is limited by the chemical equilibrium of the reaction. Operating conditions are chosen such that a close approach to equilibroum is obtained. Although, from an equilibrium standpoint lower temperature favors the production of branched-chain hydrocarbons, lower temperature also decreases the reaction rate and the degree of approach to equilibrium. Therefore, the reaction temperature is selected by balancing reaction rate, equilibrium, catalyst life and the increased tendency toward hydrocarbon decomposition by cracking at higher temperatures. Table 3 shows the yields and product quality of the reactor effluent under typical operating conditions on a once-through basis when charging a Mid-Continent hexane feed. The overall effect is primarily one of converting n-hexane (26 ASTM octane number) to neohexane and diisopropyl. The distribution in the reactor effluent is essentially independent of the composition of C_6 paraffins in the reactor charge.

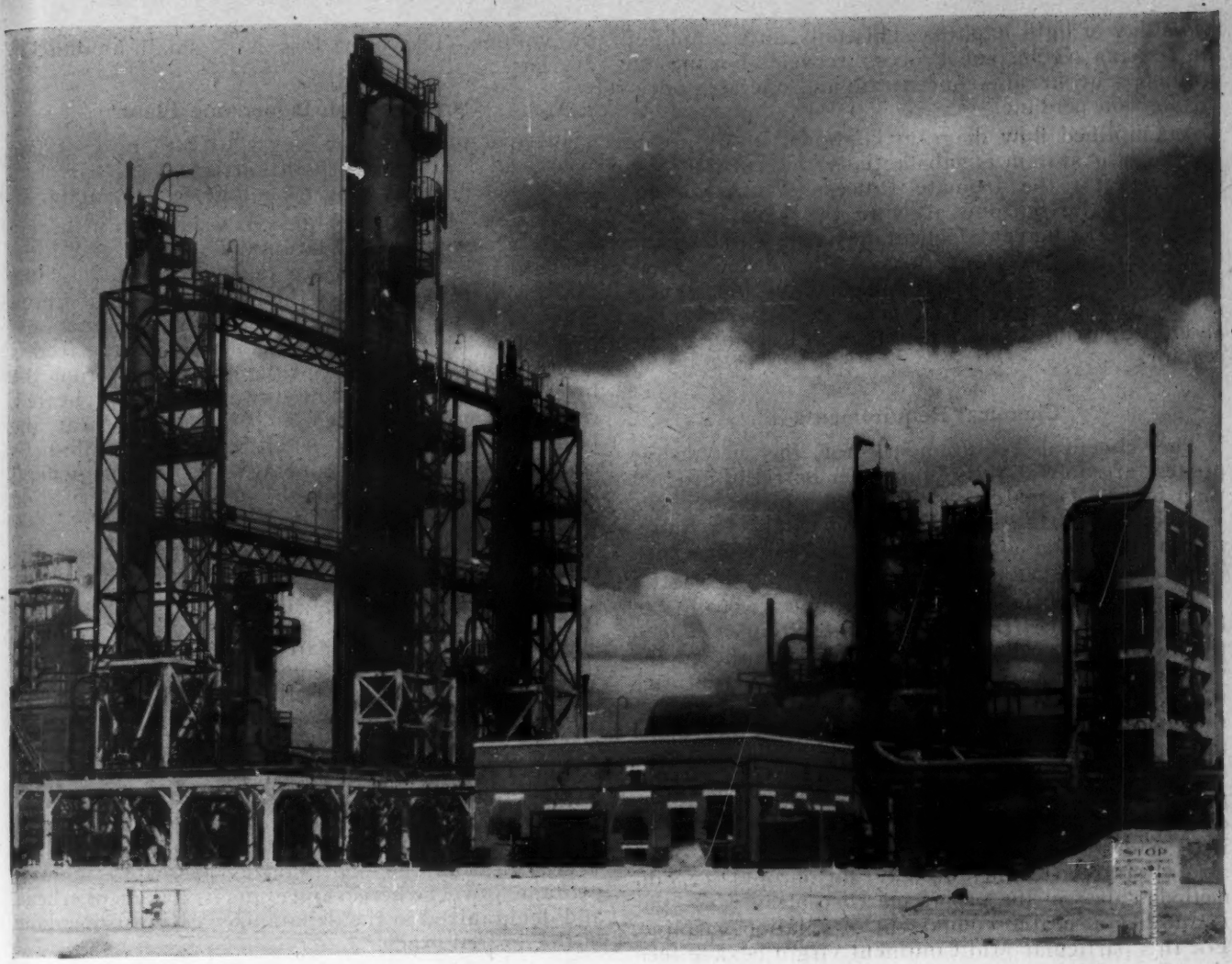
The isoparaffins produced in the process not only have high octane number but excellent lead susceptibilities as shown in Table 9.

Utah Neohexane Plant

The Salt Lake City unit of Utah Oil Refining Company charges 1750 bar-

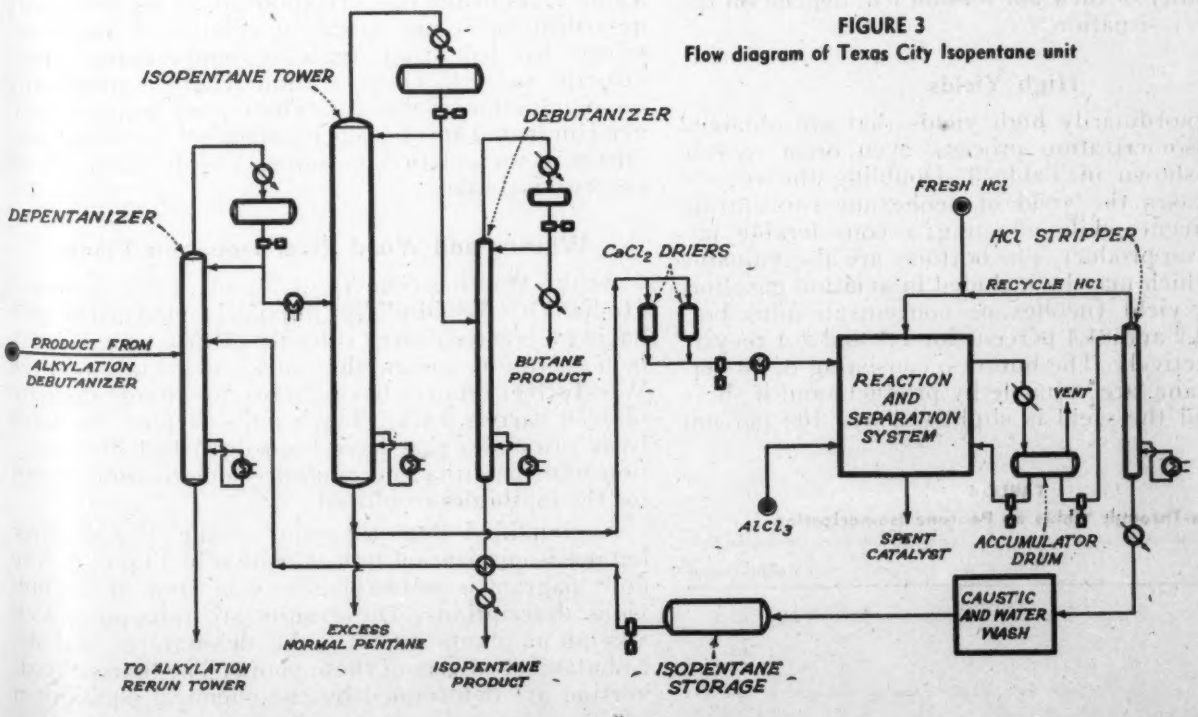
FIGURE 2
Utah Neohexane Unit. The photograph shows the reactor section of this unit.





Pan American Refining Corporation's Isopentane unit at Texas City

FIGURE 3
Flow diagram of Texas City Isopentane unit



rels a day of light naphtha. This unit, an example of the Indiana Neohexane Process, recycles hexanes to produce a neohexane concentrate and operates once-through on pentane.

A simplified flow diagram is shown in Figure 2. The reactor system is substantially the same as that described for the Isomate Process. From the debutanizer, the bottoms pass to the hexane tower. Pentanes (75 percent isopentane) and a neohexane concentrate are taken overhead while hexane recycle is removed as a bottom stream. The hexane recycle is first passed through a rerun tower to separate out about 10 percent heavy ends before returning to the reactor.

Chemical Requirements

The chemical requirements for the neohexane process are only slightly higher per barrel of product than for the isomate process in spite of the recycle. This is due to the small HCl and catalyst requirements for conversion of the recycle which has been "cleaned" by previous contact with the catalyst.

The quality of the neohexane concentrate is affected by the degree of fractionation and extent to which the hexanes are recycled. In Table 3 are shown the yield and product quality of neohexane concentrates for 1:1 and 2:1 recycle ratios compared to once-through operation when charging a virgin hexane fraction. Neohexane from virgin naphtha will always contain small amounts of cyclopentane as it is impractical to separate these hydrocarbons due to the closeness of their boiling points. Cyclopentane is in itself a desirable aviation-gasoline component. It is also desirable to include any diisopropyl (2,3-dimethylbutane) in the neohexane concentrate since this is another desirable component of aviation gasoline. For this particular Mid-Continent virgin hexane feed the effect of 1:1 recycle ratio is essentially to convert n-hexane and part of the 3-methylpentane to neohexane. Increasing the recycle ratio to 2:1 results in conversion of 2-methylpentane to neohexane product. Both 2-methylpentane and 3-methylpentane are of marginal quality for aviation gasoline and therefore the desirability of their conversion will depend on the local refinery situation.

High Yields

The extraordinarily high yields that are obtained with the isomerization process, even on a recycle basis, are shown in Table 3. Doubling the recycle ratio decreases the yield of neohexane concentrate only 2 percent while effecting a considerable improvement on product. The bottoms are also valuable products which may be included in aviation gasoline. The liquid yield (neohexane concentrate plus bottoms) is 94.2 and 91.4 percent for 1:1 and 2:1 recycle ratio, respectively. The butanes, consisting of 75 percent isobutane, are valuable by-products and if these are included the yield is slightly above 100 percent by volume. The only loss is a small amount to dry gas.

TABLE 4

Once-Through Yields on Pentane Isomerization

Reactor Effluent	Weight, Percent
Dry Gas	0.1
Butane	1.7
Isopentane	62.0
n-Pentane	34.8
C_6 and Heavier	1.4

Pan American Isopentane Plant

Just completed at the Texas City refinery of Pan American Refining Corporation is a 1620 barrels a day unit for isomerizing n-pentane to isopentane.

As shown by the simplified flow diagram in Figure 3, product from the alkylation debutanizer enters the dependentanizer. Pentanes are taken overhead and the bottom stream sent to the alkylation unit rerun tower. The pentanes enter the isopentane fractionation tower where isopentane contained in the feed is fractionated out. The n-pentane is taken from the bottom of the isopentane tower, dried, preheated, combined with the HCl and introduced near the bottom of the reactor. A small amount of inhibitor is added. The reactor itself operates on the same general principle as in the case of the naphtha isomerization reactor.

The pentane isomate, passing overhead from the reactor, is cooled and passes to the accumulator drum. This drum acts as a gas separator as well as a catalyst settling drum. The uncondensed gases, principally methane, are eliminated by intermittent or continuous venting. The accumulator liquid is pumped to the HCl stripper and HCl recycle taken overhead. The bottom product from the HCl stripper is cooled, washed with caustic and water to eliminate traces of HCl and is returned to the dependentanizer. The isomerized pentanes are returned to the dependentanizer instead of directly to the isopentane tower to remove a small amount of heavy ends. As described for the feed, the overhead from the dependentanizer passes to the isopentane tower where isopentane is taken overhead and debutanized in the debutanizer giving isopentane of the desired grade.

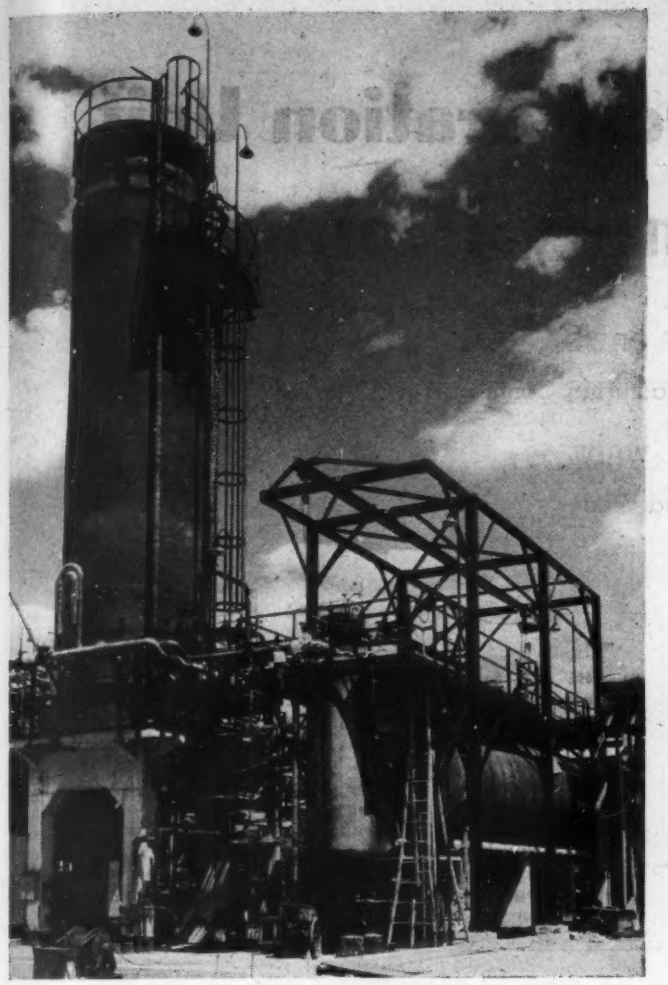
Typical Yields

In Table 4 typical yields are shown for a one-through operation. The concentration of isopentane in the reactor effluent is limited by the chemical equilibrium at the temperature of operation as shown in Table 2. As in the isomerization processes previously described, optimum operating conditions are determined by balancing reaction temperature, space velocity and HCl concentration. There is practically no degradation to dry gas. The C_6 and heavier product eliminated in the dependentanizer are valuable constituents for aviation gasoline. The butanes are 80 percent isobutane.

Whiting and Wood River Isobutane Plants

At the Whiting refinery of Standard Oil Company (Indiana) a liquid-phase, butane isomerization unit having a reactor charge capacity of 4530 barrels a day is in operation, and another unit is in operation at the Wood River refinery having a reactor charge capacity of 4250 barrels a day. These units employ the same basic principles that have been described in connection with naphtha and pentane isomerization except for the inhibitors employed.

A simplified flow diagram of the Wood River butane isomerization unit is shown in Figure 4. The flow diagram is self-explanatory in view of the previous descriptions. These units are integrated with alkylation plants and use the debutanizer and deisobutanizer towers of these plants. The limits of conversion are determined by the chemical equilibrium



Wood River Isobutane Unit

TABLE 5
Once-Through Yields on Butane Isomerization

Reactor Effluent	Weight, Percent
Dry Gas	0.7
Isobutane	50.0
n-Butane	48.6
C_5 and Heavier	0.7

as shown in Table 2. A typical example of one-through butane isomerization is given in Table 5.

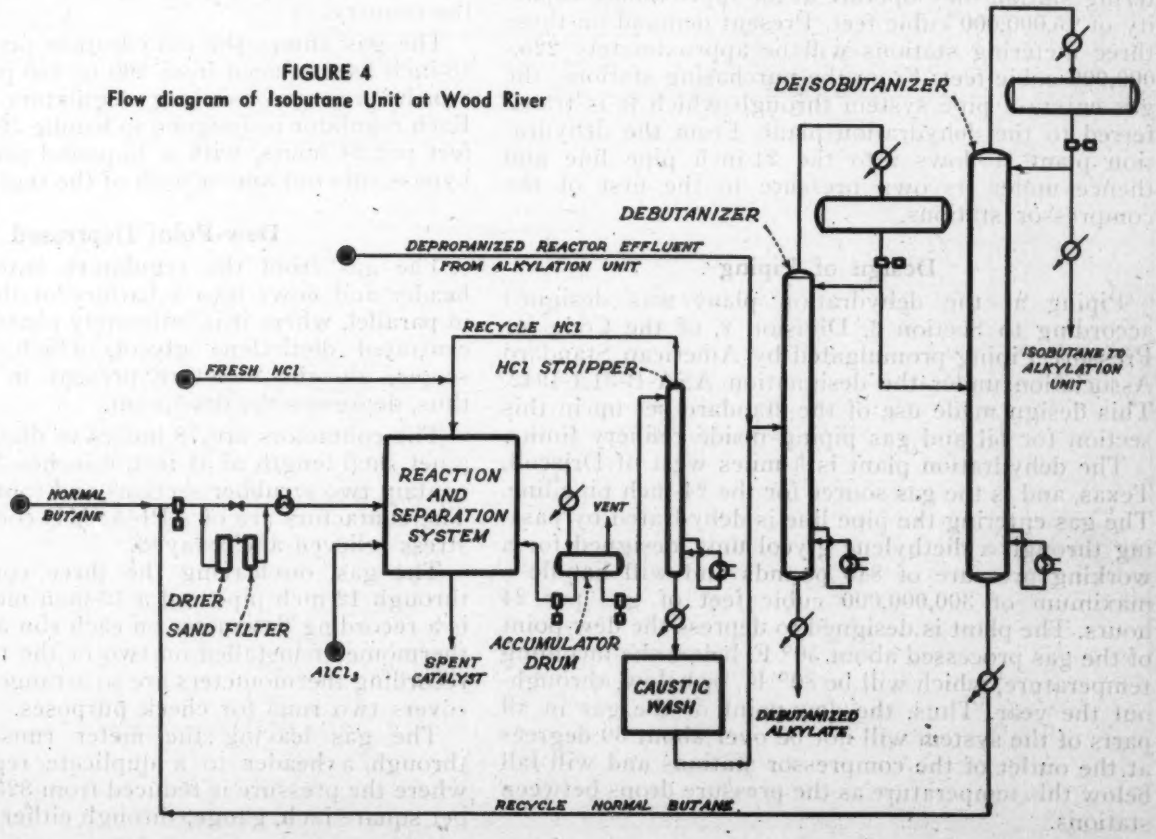
Chemical and Engineering Development

The study of the isomerization of paraffin hydrocarbons has been conducted in the laboratories of this company for more than a decade. Several thousand laboratory experiments were made to accumulate extensive background in the field of isomerization. Pilot-plant development based on these fundamental studies resulted in operable, continuous, and from a mechanical viewpoint, rather simple processes. As soon as the necessity for rapid expansion in aviation gasoline production was realized, the results of the exploratory and pilot plant experiments were carefully appraised from processing and mechanical engineering aspects and designs of large-scale plants undertaken.

Projected operations on a large scale necessitated reconsideration of problems concerning the handling of the various materials used in the processes at a time when special equipment was difficult to obtain. Means for continuously injecting granular materials into vessels operating under pressure were improvised, using types of equipment already available. Many other problems were successfully solved in the construction of the five plants just described.

These commercial installations represent the combined efforts of the research, operating and engineering departments and the authors acknowledge the contributions by many members of the company to the success of this development.

FIGURE 4
Flow diagram of Isobutane Unit at Wood River



High-Pressure Dehydration Unit Conforms to Refinery Piping Code

HAROLD F. DAWE

Stearns-Roger Manufacturing Company

HENRY N. WADE

Parkhill and Wade

THE dehydration plant on the system of Tennessee Gas & Transmission Company is designed to complete the process of preparing natural gas for use as a fuel. Removal of hydrates begins at the well separators and continues through the high-pressure-absorption plants through which the stripped gas passes before entering the transmission system, which will deliver gas to the industrial area of Eastern Ohio and West Virginia.

Gas enters three purchase-gas metering stations under natural well pressure. The stations are located at the Wardner and Coastal recycling plants of Chicago Corporation, and at the Gulf Plains plant of Gulf Plains Corporation.

The Wardner and Gulf Plains metering stations each has a maximum 24-hour capacity of approximately 150,000,000 cubic feet, while the Coastal metering station may operate at an approximate capacity of 75,000,000 cubic feet. Present demand on these three metering stations will be approximately 225,000,000 cubic feet. From the purchasing stations, the gas enters a pipe system through which it is transferred to the dehydration plant. From the dehydration plant it flows into the 24-inch pipe line and thence under its own pressure to the first of the compressor stations.

Design of Piping

Piping at the dehydration plant was designed according to Section 3, Division 2, of the Code for Pressure Piping promulgated by American Standard Association under the designation ASA-B-31.1-1942. This design made use of the standard set up in this section for oil and gas piping inside refinery limits.

The dehydration plant is 5 miles west of Driscoll, Texas, and is the gas source for the 24-inch pipe line. The gas entering the pipe line is dehydrated by passing through a diethylene glycol unit, designed for a working pressure of 840 pounds and will handle a maximum of 300,000,000 cubic feet of gas per 24 hours. The plant is designed to depress the dew-point of the gas processed about 50° F. below the incoming temperature, which will be 80° F., or below, throughout the year. Thus, the dew-point of the gas in all parts of the system will not be over about 30 degrees at the outlet of the compressor stations and will fall below this temperature as the pressure drops between stations.

THE unit for dehydration of gas on the system of Tennessee Gas & Transmission Company is of especial interest because it was designed in keeping with code requirements for oil and gas piping inside refinery limits.

This unit also completes hydrate removal, which is a part of the process at three cycling plants through which the charge for the new line passes.

This description was prepared as a part of the longer article, which included similar information on the compressor stations along the 25-inch line, which is 1265 miles long. First gas was delivered through the system, November 1, 1944.

Experience has shown that this dew-point is adequate to protect against freezing or the formation of hydrates on all transmission lines, except possibly one or two in the coldest, most northerly parts of the country.

The gas enters the dehydration plant through an 18-inch line reduced from 900 to 840 pounds through 8-inch pressure reducing regulators, in duplicate. Each regulator is designed to handle 225,000,000 cubic feet per 24 hours, with a 35-pound pressure drop. A bypass cuts out one or both of the regulators.

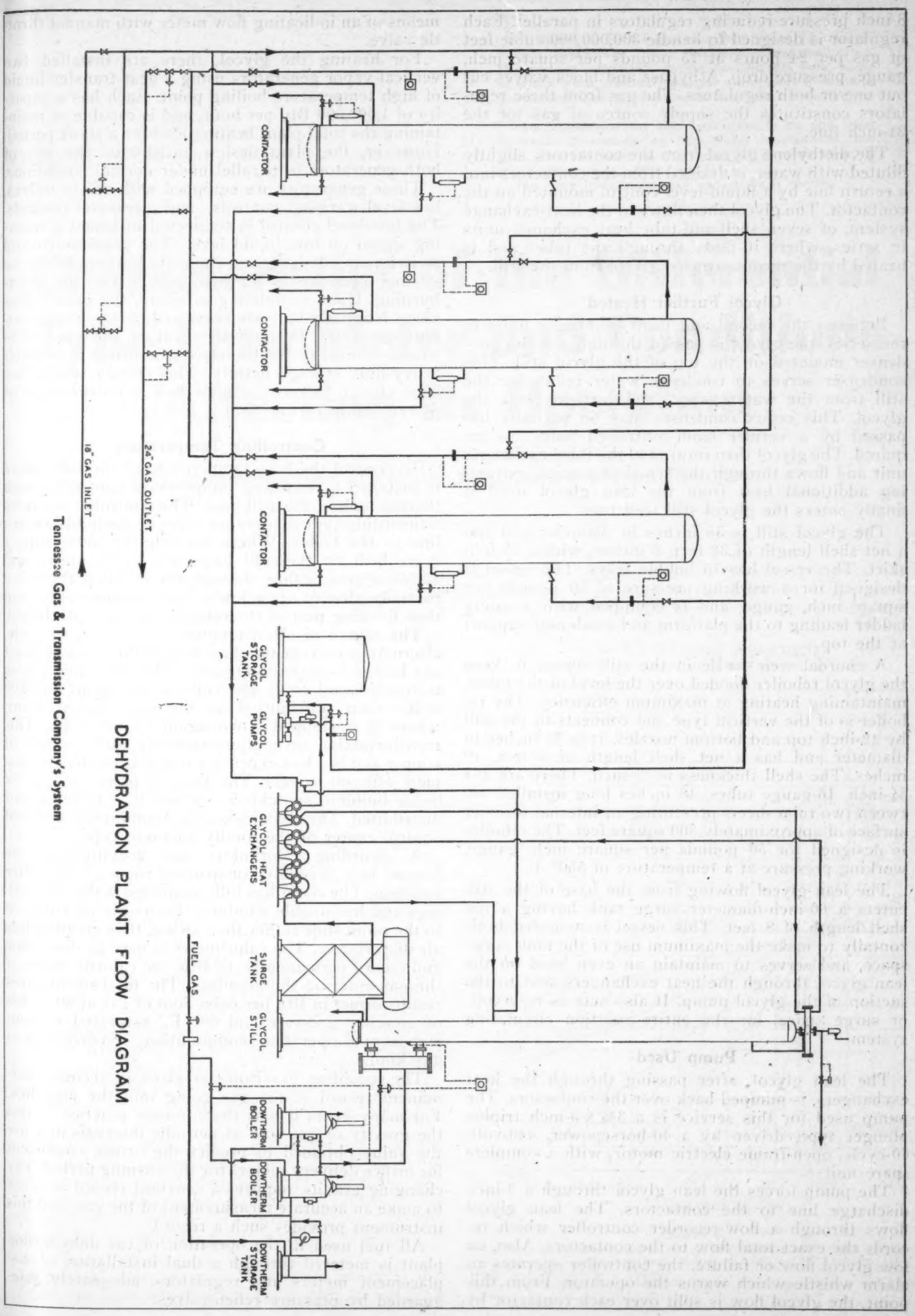
Dew-Point Depressed

The gas from the regulators enters an 18-inch header and flows into a battery of three contactors in parallel, where it is intimately contacted with concentrated diethylene glycol, which, being hygroscopic, absorbs moisture present in the gas, and, thus, depresses the dew-point.

The contactors are 78 inches in diameter and have a net shell length of 31 feet, 6 inches. The units each contain two scrubber sections and four contact trays. The contactors are of API-ASME code design, fully stress relieved and x-rayed.

The gas, on leaving the three contactors, flows through 12-inch pipe and a 12-inch meter run. There is a recording flowmeter on each run and a recording thermometer installed on two of the three runs. The recording thermometers are so arranged that one unit covers two runs for check purposes.

The gas leaving the meter runs is conducted through a header to a duplicate regulator setting where the pressure is reduced from 825 to 750 pounds per square inch, gauge, through either or both of two



DEHYDRATION PLANT FLOW DIAGRAM

Tennessee Gas & Transmission Company's System

8-inch pressure-reducing regulators in parallel. Each regulator is designed to handle 300,000,000 cubic feet of gas per 24 hours at 75 pounds per square inch, gauge, pressure drop. A bypass and block valves cut out one or both regulators. The gas from these regulators constitutes the supply source of gas for the 24-inch line.

The diethylene glycol from the contactors, slightly diluted with water, is drained from the contactors into a return line by a liquid-level control mounted on the contactor. The glycol then flows to the heat-exchange system, of seven shell-and-tube heat exchange units in series, where it flows through the tubes and is heated by the reconcentrated glycol from the still.

Glycol Further Heated

Between the second and third exchanger units in the series, the glycol is passed through a reflux condenser mounted on the top of the glycol still. This condenser serves to condense water reflux for the still from the water vapor, and further heats the glycol. This reflux condenser may be partially bypassed by a vernier hand-controlled valve, as required. The glycol then returns to the third exchanger unit and flows through the remaining units, extracting additional heat from the lean glycol until it finally enters the glycol still feed tray.

The glycol still is 30 inches in diameter and has a net shell length of 32 feet, 6 inches, with a 10-foot skirt. The vessel has 15 bubble trays. The vessel is designed for a working pressure of 50 pounds per square inch, gauge, and is equipped with a safety ladder leading to the platform and condenser support at the top.

A chordal weir baffle in the still serves to keep the glycol reboiler flooded over the level of the tubes, maintaining heating at maximum efficiency. The reboiler is of the vertical type and connects to the still by 12-inch top and bottom nozzles. It is 24 inches in diameter and has a net shell length of 6 feet, 10 inches. The shell thickness is ¼-inch. There are 454 ¾-inch, 16-gauge tubes, 48 inches long installed between two tube sheets presenting an internal transfer surface of approximately 300 square feet. The reboiler is designed for 50 pounds per square inch, gauge, working pressure at a temperature of 550° F.

The lean glycol flowing from the base of the still enters a 60-inch-diameter surge tank having a net shell length of 8 feet. This vessel is mounted horizontally to make the maximum use of the tank surge space, and serves to maintain an even head on the lean glycol through the heat exchangers, and to the suction of the glycol pump. It also acts as reservoir, or surge space, for the entire solution circulating system.

Pump Used

The lean glycol, after passing through the heat exchangers, is pumped back over the contactors. The pump used for this service is a 3¾ x 5-inch triplex plunger type, driven by a 40-horsepower, 440-volt, 60-cycle, open-frame electric motor, with a complete spare unit.

The pump forces the lean glycol through a 3-inch discharge line to the contactors. The lean glycol flows through a flow-recorder controller which records the exact total flow to the contactors. Also, on low glycol flow or failure, the controller operates an alarm whistle which warns the operator. From this point, the glycol flow is split over each contactor by means of an indicating flow meter with manual throttle valve.

For heating the glycol, there are installed two vertical vapor generators using a heat transfer liquid of high temperature boiling point. Each has a capacity of 1,000,000 Btu per hour, and is capable of maintaining the total plant heating load for a short period. However, the plant design anticipates the use of both generators in parallel under normal conditions.

These generators are equipped with safety valves, low-level-warning controls, and pressure controls. The low-level control is connected to sound a warning signal on low liquid level. The pressure-control switch cuts off the gas to the main burners when the desired pressure is reached, but leaves the pilots burning. Upon complete gas failure, the pilot valves close. Normally they are energized by an electric current generated through the heat of the pilot. The source of energy for the electric controls is a 6-volt heavy-duty storage battery. This energy source has been chosen as most reliable and is independent of power failure to the plant.

Controlling Temperature

To control the base temperature of the still, there is installed a recording temperature controller with thermo bulb in the still base. The controller operates a throttling-type diaphragm valve in the liquid-return line to the boiler. Where the reboiler must supply more heat to the still base, the valve opens and allows a greater flow through the reboiler, the valve partially closing upon lower heat requirements, and thus flooding part of the reboiler surface with liquid.

The source of electric power is 440-volt, 60-cycle, alternating current purchased from the Coastal plant of Chicago Corporation nearby. The generated power is transformed from 440 volts at the plant to 2300 volts, then transmitted to the dehydration plant, where it is stepped down again to 440 volts. This transformation saves approximately 4700 pounds of copper and is a less expensive installation than a complete 440-volt system. The 440-volt power enters the boiler building switchboard where it is metered and distributed. The switchboard is a completely unitized control center of the totally enclosed type.

A recording calorimeter and gravitometer are housed in a specially constructed room of the office building. The room has fully insulated walls and ceilings and has double windows. Doors giving entrance to the room slide rather than swing, thus creating less air disturbance. The calorimeter is used to determine and record permanently, in Btu, the calorific value of the gas entering the pipe line. The instrument gives results direct in Btu per cubic foot of gas at 30 inches of mercury pressure and 60° F., saturated without any manual operation, computation, or correction of any kind.

The recording gravitometer gives an accurate permanent record of the gas going into the pipe line. For many years it was the common practice to test the gravity of gas sold at periodic intervals and use the value obtained to predict the orifice coefficient for orifice delivery meters for the ensuing period. The changing gravity requires a constant record in order to make an accurate measurement of the gas, and this instrument provides such a record.

All fuel used in the operation of the dehydration plant is metered through a dual installation of displacement meters and regulators, adequately safeguarded by pressure relief valves.

PART 2

L. K. SPINK
The Foxboro Company, Foxboro, Massachusetts

THE discussion in the previous installment (*Petroleum Refiner*, September, 1944) was general and qualitative. The present installment covers specific test data, some of which were used as bases for statements in the first installment, and some of which are given here for the first time.

This installment not only tells what to do and what to avoid in considering flow-meter applications, but also cites the penalties in terms of percent error, if these rules are not observed.

The third installment will appear next month.

Characteristics of the Differential Type Flow Meter and Conditions Affecting Its Operation

Quantitative Effect of Various Influences on Meter Readings

THE usual pressure-measuring devices record or indicate pressures above or below atmospheric. The actual total pressure applied to a compressible fluid is the absolute pressure in the conduit. This is equal to gauge pressure plus atmospheric pressure. It is usual to assume a barometric pressure which is normal for the locality, but barometric pressure is likely to be higher in cold, dry, clear weather and lower in warm, humid, stormy weather. Errors due to assuming a 14.4-pounds-per-square-inch barometer for flow calculations are shown in Figure 4.

The effects of errors in the readings of static pressure on gas are shown in Figure 5. While these apply specifically to true gases they give a very close approximation of the error which would result in steam or other vapor measurements, if, for instance, pressure readings were taken at the meter without correcting for the head of condensate. Each 27.7 inches of water vertical head represents 1 pound per square inch.

Acceleration of gravity affects meter readings through its effect on the amount of pressure imposed by an inch of water or other medium used to calibrate or to actuate the differential measuring mechanism. The acceleration of gravity varies slightly with altitude and with latitude. The question of its effect on flow measurement arises occasionally, and we have prepared a table of correction factors to prove that the amount of correction involved is negligible (see Table 2).

The compressibility of a petroleum oil becomes appreciable at temperatures above 70 percent of the molal average critical temperature of its constituents. The amount of correction is shown in Figure 6. The temperature at which this effect usually becomes appreciable at various A.P.I. gravities is shown in Table 2.

When the mercury in a differential gauge is displaced, the fluid which displaces it adds to the pressure on the high-pressure or depressed side of the manometer, thus causing the mercury U-gauge or float-type meter to read high. This effect is so low it

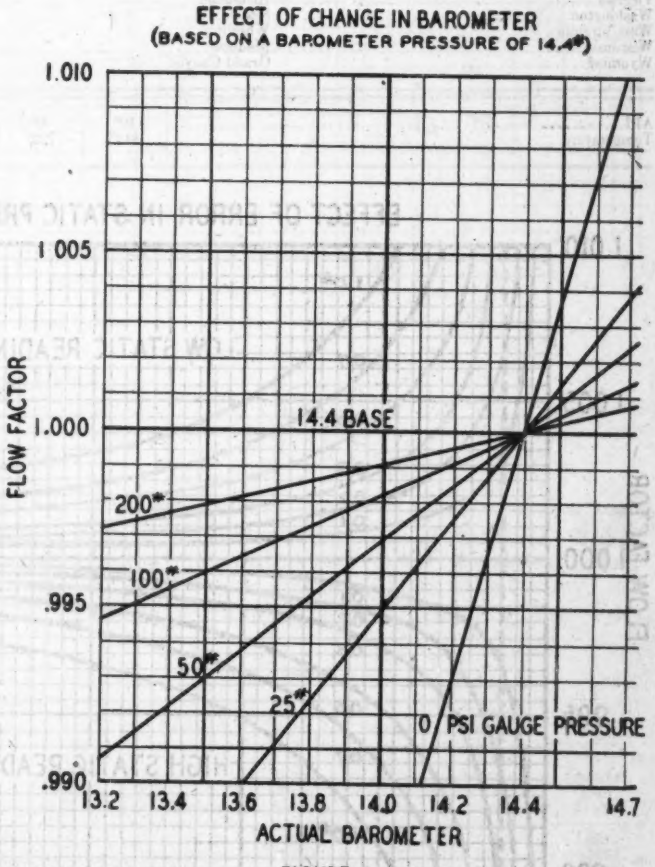


FIGURE 4

From "Practical Application of A.G.A. Gas Measurement Committee Report No. 2," by J. E. Overbeck, Series 39, No. 7—III, January, 1939, West Virginia University Bulletin.

NOTE: A high flow factor indicates a low gas meter reading, and vice versa.

TABLE 2

Correction for Acceleration of Gravity Other Than 32.16 Ft./Sec.²

(Reference: Smithsonian Physical Tables Pg. 426)
32.16 Ft./Sec.² = 980.2368 cm./Sec.² K = 345.92

		Latitude	Elevation Feet	Correction for K=345.92	Correction for K=345.755	
Alabama	Birmingham	33° 30.8′	587.	.99964	1.00012	
Arizona	Grand Canyon	36° 5.3′	2786.	.99961	1.00009	
Arizona	Yuma	32° 43.3′	177.	.99964	1.00012	
Arkansas	Arkansas City	33° 36.5′	144.	.99968	1.00016	
Arkansas	Little Rock	34° 45.0′	292.	.99974	1.00022	
California	Mt. Hamilton	37° 20.4′	4206.	.99971	1.00019	Observatory
California	San Francisco	37° 47.5′	374.	.99986	1.00034	
Colorado	Colorado Springs	38° 50.7′	6040.	.99962	1.00010	
Colorado	Denver	39° 40.6′	5374.	.99968	1.00016	University
Colorado	Pikes Peak	38° 50.3′	14085.	.99936	.99984	
District of Columbia	Washington	38° 56.3′	338.	.99993	1.00041	Bureau of Stds.
Florida	Key West	24° 33.6′	4.	.99935	.99983	
Georgia	Atlanta	33° 45.0′	1063.	.99964	1.00012	Capitol
Idaho	Boise	43° 37.2′	2694.	.99999	1.00047	
Illinois	Chicago	41° 47.4′	597.	1.00002	1.00050	University
Indiana	Terre Haute	39° 28.7′	495.	.99992	1.00040	
Iowa	Fort Dodge	42° 31.0′	1116.	1.00004	1.00052	
Kansas	Wallace	38° 54.7′	3297.	.99975	1.00023	
Louisiana	New Orleans	29° 57.0′	7.	.99953	1.00001	
Massachusetts	Cambridge	42° 22.8′	46.	1.00008	1.00056	Observatory
Massachusetts	Worcester	42° 16.5′	558.	1.00005	1.00053	
Maryland	Baltimore	39° 17.8′	98.	.99993	1.00041	University
Maine	Calais	45° 11.2′	125.	1.00020	1.00068	
Michigan	Grand Rapids	42° 58.0′	774.	1.00007	1.00055	
Minnesota	Minneapolis	44° 58.7′	840.	1.00019	1.00067	
Montana	Miles City	46° 24.2′	2356.	1.00015	1.00063	
Nevada	Winnemucca	40° 58.4′	4301.	.99980	1.00028	
New Hampshire	Lancaster	44° 29.5′	856.	1.00013	1.00061	
New Jersey	Princeton	40° 21.0′	210.	.99997	1.00045	
New Mexico	Las Vegas	35° 35.8′	6431.	.99947	.99995	
New York	Ithaca	42° 7.1′	810.	1.00003	1.00051	University
New York	New York	40° 48.5′	125.	1.00002	1.00050	University
North Carolina	Beauforte	34° 43.1′	4.	.99974	1.00022	
North Carolina	Charlotte	35° 13.8′	748.	.99974	1.00022	
North Dakota	Pembina	48° 58.1′	797.	1.00035	1.00083	
Ohio	Cincinnati	39° 8.3′	804.	.99988	1.00036	Observatory
Ohio	Cleveland	41° 30.4′	689.	1.00000	1.00048	
Oklahoma	Tulsa	36° 9.6′	711.	.99976	1.00024	
Pennsylvania	Philadelphia	39° 57.1′	53.	.99998	1.00046	University
Pennsylvania	Pittsburgh	40° 27.4′	771.	.99994	1.00042	
South Carolina	Charleston	32° 47.2′	20.	.99965	1.00013	
South Dakota	Mitchell	43° 41.8′	1339.	1.00007	1.00055	University
Tennessee	Knoxville	35° 57.7′	919.	.99973	1.00021	
Tennessee	Memphis	35° 8.8′	263.	.99975	1.00023	
Texas	Austin	30° 17.2′	620.	.99951	.99999	University
Texas	Dallas	32° 47.0′	436.	.99963	1.00011	
Texas	El Paso	31° 46.3′	3760.	.99943	.99991	
Utah	Green River	38° 59.4′	4078.	.99969	1.00017	
Utah	Salt Lake City	40° 46.1′	4338.	.99978	1.00026	
Virginia	Richmond	37° 32.2′	98.	.99986	1.00034	
Washington	Seattle	47° 39.6′	190.	1.00025	1.00073	University
West Virginia	Wheeling	40° 4.0′	673.	.99992	1.00040	
Wisconsin	Madison	43° 4.6′	886.	1.00007	1.00055	University
Wyoming	Grand Canyon	44° 43.3′	7829.	.99983	1.00031	

API	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
Temperature	842°	702°	534°	418°	345°	292°	243°	191°	145°	107°

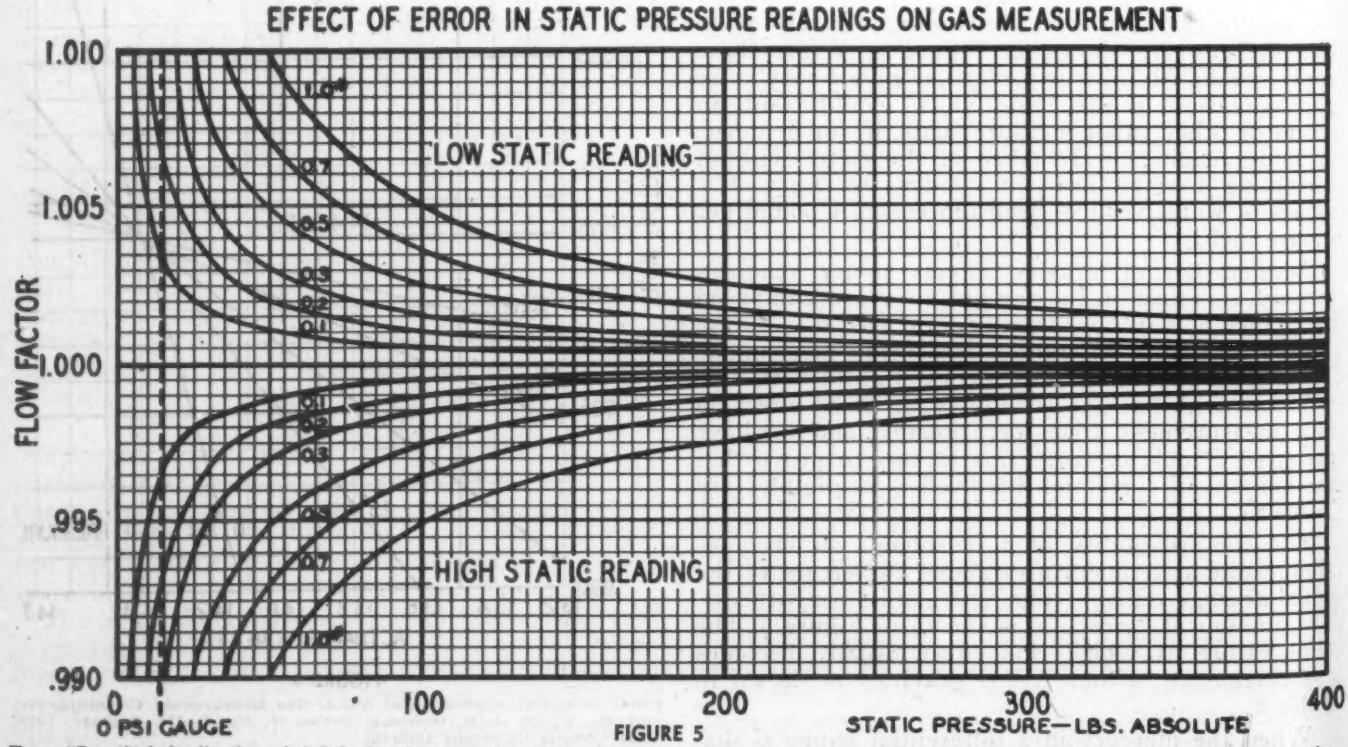


FIGURE 5

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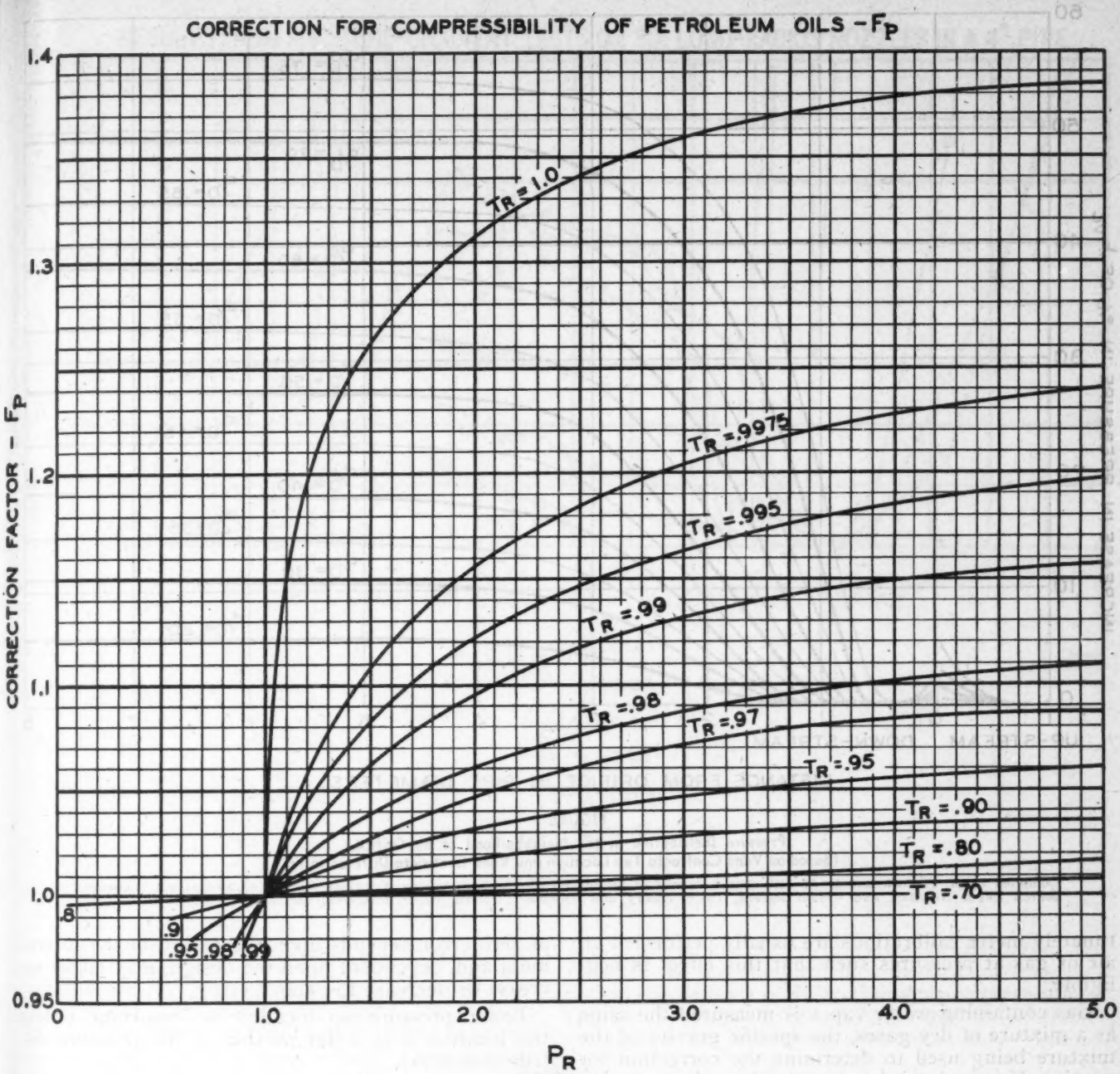


FIGURE 6

Compressibility of Petroleum Products

From "High Temperature Expansion of Petroleum Fractions" by K. M. Watson, E. F. Nelson, and George B. Murphy, Universal Oil Products Co. (Oil & Gas Journal, November 12, 1936).

may be neglected on low-pressure-gas measurement, unless liquid seals are used. Several examples selected at random will show that this effect is not negligible at high pressure. At a pressure of 2100 pounds per square inch and 32° F., for instance, the density of methane is approximately 8.5 pounds per cubic foot, and the effect of this dense gas reduces the coefficient of a mercury float type meter roughly .5 percent. A gas of .9 specific gravity at the same temperature and pressure has a density of approximately 22.5 pounds per cubic foot, and this effect reduces the coefficient roughly 1⅓ percent. The increase is out of proportion to the increase in specific gravity, because the heavier gas is more compressible. The flow correction factor is $\sqrt{1-.00118W_s}$, in which W_s is the density in pounds per cubic foot of gas or liquid which displaces the mercury.

The reading of a water column, which is used as a standard in calibrating commercial meters, is also affected in a similar manner by the density of the air displacing the water. Since the displacement is roughly 13.6 times as great as that of mercury, the effect on the reading is 13.6 times as great. For-

TABLE 3

Temp. °F.	Column 1 Mercury	Column 2 Actual Flow Factor	Column 3 Water	Column 4 Ratio Column 1 / Column 3	Column 5 Apparent Flow Factor
95°	.9973	.9986	.9958	1.0015	1.0007
86°	.9982	.9991	.9974	1.0004	1.0002
77°	.9991	.9995	.9988	1.0001	1.0000
68°	1.0000	1.0000	1.0000	1.0000	1.0000
59°	1.0009	1.0004	1.0009	1.0000	1.0000
50°	1.0018	1.0009	1.0015	1.0001	1.0000
41°	1.0027	1.0013	1.0018	1.0009	1.0004

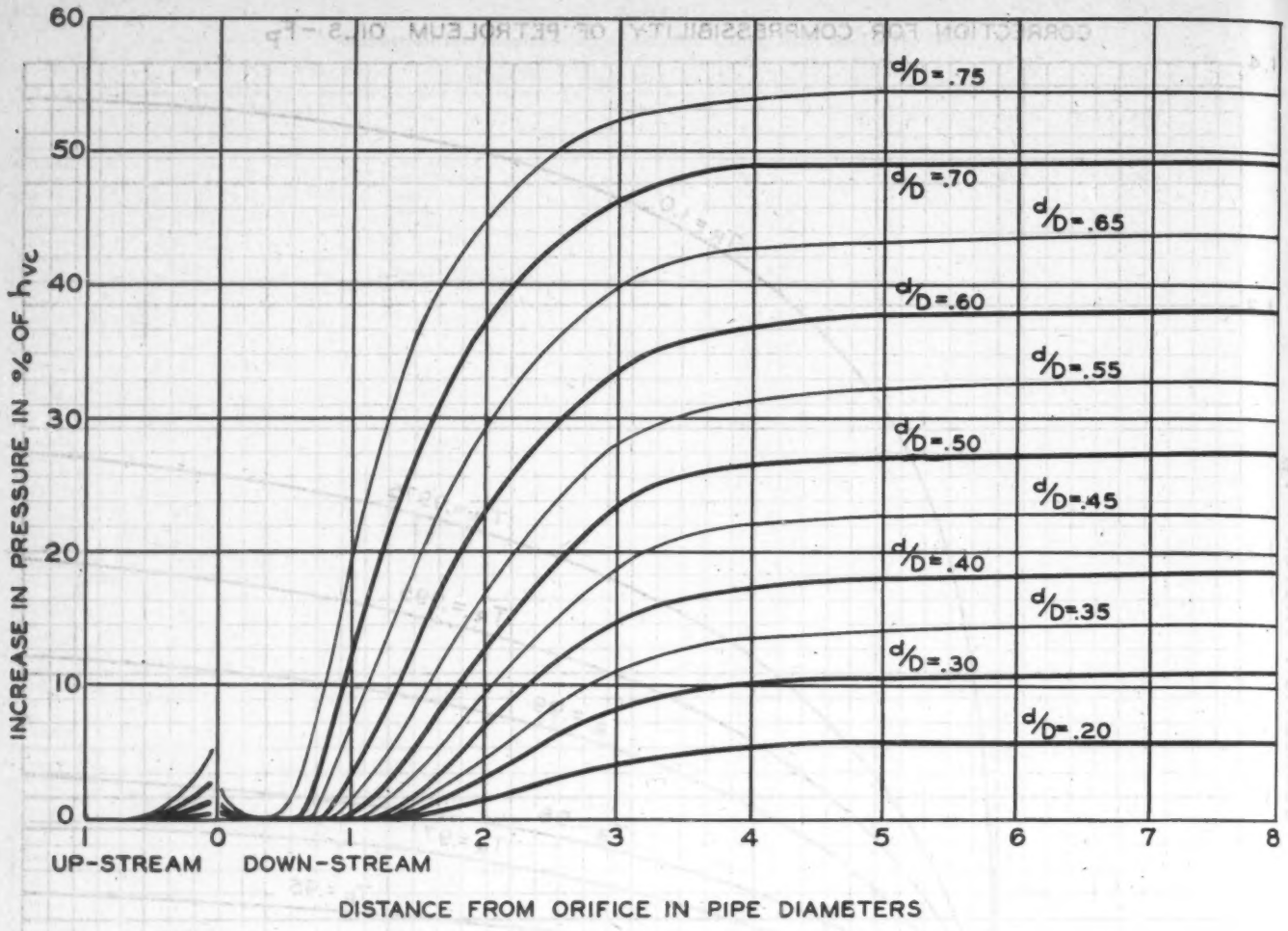


FIGURE 7

Pressure Distribution in the Neighborhood of an Orifice.
(Based on Vena Contracta Tap Location and Vena Contracta Differential)

Compiled by H. J. Cook and D. M. Hill from: Bureau of Standards Research Paper No. 335, and "Fluid Meters, Their Theory and Application" by the American Society of Mechanical Engineers.
NOTE: h_{vc} = differential pressure (vena contracta taps).

tunately meter calibrations are usually performed on air or gas at pressures such that this effect is negligible.

Gas containing water vapor is measured the same as a mixture of dry gases, the specific gravity of the mixture being used to determine the correction for gravity. If it is desired to reduce the volume to dry gas, partially saturated, or saturated gas volume at base condition, an additional factor must be applied. This factor is calculated from the following formula:

$$\text{Factor} = \frac{P - R_f P_{wf}}{P} \times \frac{P_b}{P_b - R_b P_{wb}}$$ in which P = flowing pressure in pounds per square inch absolute

R_f = % relative humidity of flowing gas ÷ 100
R_b = % relative humidity specified by contract ÷ 100
P_{wf} = water vapor pressure at flowing temperature, #/sq. in. abs.
P_{wb} = water vapor pressure at base temperature, #/sq. in. abs.
P_b = pressure base, #/sq. in. abs.

The effect of temperature on the density of mercury influences the calibration of any mercury-float-type instrument. At normal room temperatures the effect on the density of water so closely approximates that of mercury that the error is obscured. Taking the density at 68° F. as a reference point, Table 3 shows the variation for mercury and for water.

The above discussion does not aply to errors in zero caused by change in temperature. The amount of zero error depends upon the design of the instrument and, dependent upon the design, may either increase or decrease the above error.

Exact pressure-tap location is important unless the location is in a flat portion of the pressure-distribution curve.

Flat pressure points are located at the vena contracta and at 8 pipe diameters downstream; also at the flange tap 1-inch downstream from the face of the plate except on high d/D ratios. A rapidly changing pressure is a sign of a turbulent condition, and readings in such locations are not as reliable as those taken at the flat portions. An approximate flow calculation for any tap location may be made however, by adding the upstream readings from Figure 7 to 100, subtracting the downstream readings, dividing 100 by the resultant figure, and then extracting the square root, to obtain a correction factor to apply to the vena contracta coefficient.

Similar curves for flow nozzles are shown in Figure 8.

Good practice requires that the pressure tap hole be not greater than ⅛ the diameter of the pipe and the pipe be brought to within ¼-inch of the face of the orifice plate. The amount and direction of the error resulting from deviation from these rules are shown in Figures 9, 10 and 11.

Good practice also demands that the orifice thickness be less than ⅛ the diameter of the orifice. The

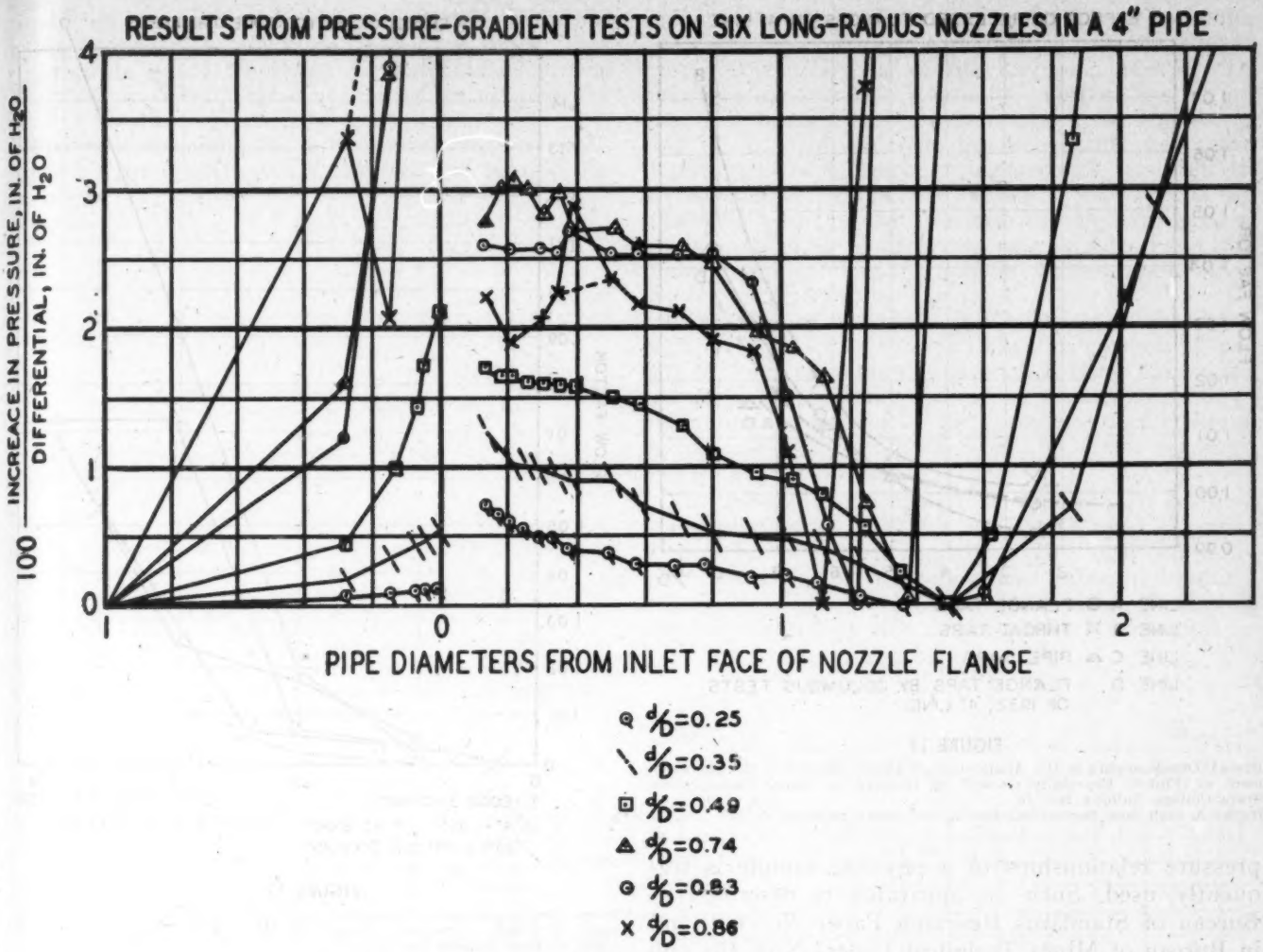


FIGURE 8

From "Some Results from Research on Flow Nozzles" by H. S. Bean and S. R. Beitler, April, 1938, A.S.M.E. Transactions Volume 60, No. 3.

effect of deviation from this rule is shown in Figure 12.

Supercompressibility

So much has been written on the subject of supercompressibility that little can be added. Several other names are in common use for the deviation from approximate gas laws; the one above is used by the American Gas Association. The application of this factor to gas measurement is necessitated by the use of the approximate gas laws in calculating the densities in the standard flow-meter equations.

Several methods of determining the supercompressibility characteristic for gas mixtures are available. Equipment for measuring the temperature, volume,

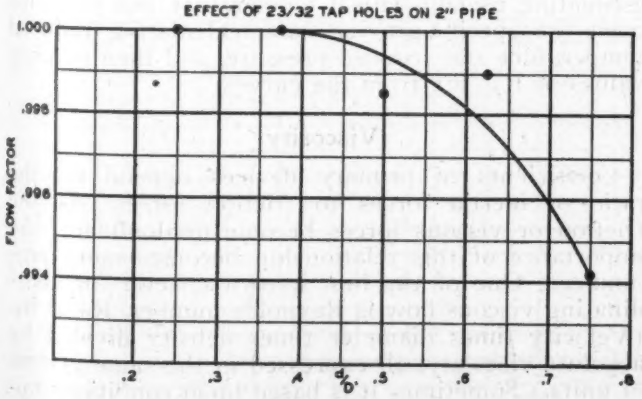


FIGURE 9

Derived from "Determination of the Effect of Certain Installation Conditions on the Coefficients of Sharp-Edged Orifices" by S. R. Beitler and J. E. Overbeck, February, 1937, A.S.M.E. Transactions, Volume 59, No. 2. NOTE: A low flow factor indicates a high meter reading.

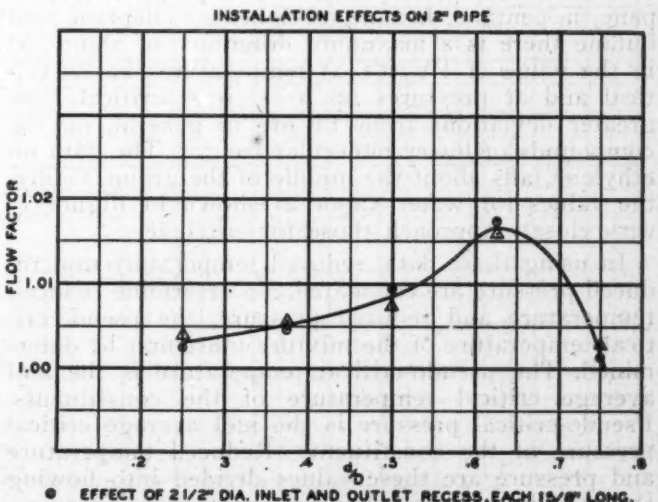


FIGURE 10

Derived from "Determination of the Effect of Certain Installation Conditions on the Coefficient of Sharp-Edged Orifices" by S. R. Beitler and J. E. Overbeck, February, 1937, A.S.M.E. Transactions, Volume 59, No. 2. NOTE: A high flow factor indicates a low meter reading.

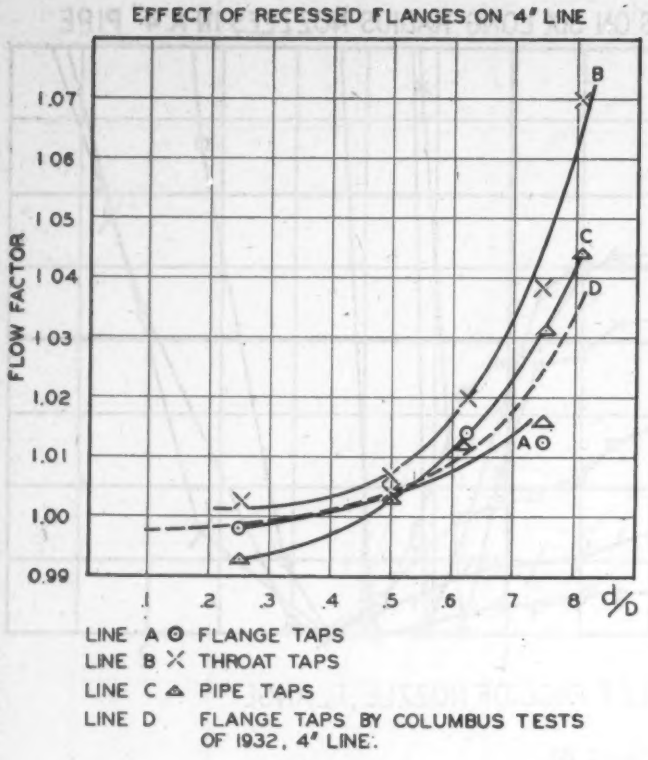


FIGURE 11

From "Developments in the Application of Orifice Meters to the Measurement of Fluids, Especially Gases" by Howard S. Bean, Pennsylvania State College Bulletin No. 20.
NOTE: A high flow factor indicates a low meter reading.

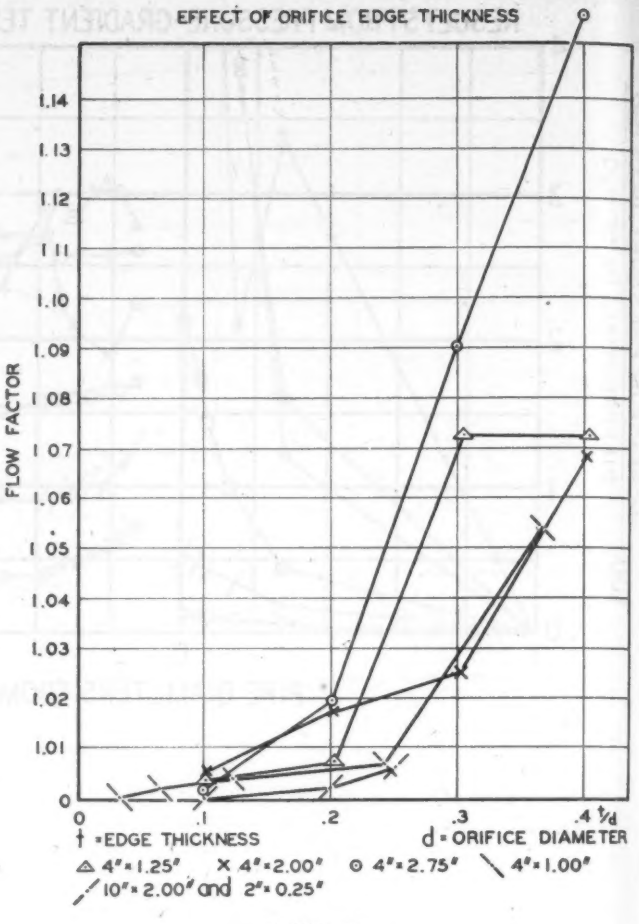


FIGURE 12

From "Developments in the Application of Orifice Meters to the Measurement of Fluids, Especially Gases" by Howard S. Bean, Pennsylvania State College Bulletin No. 20.
NOTE: A high flow factor indicates a low meter reading.

pressure relationships of a physical sample is frequently used. Such an apparatus is described in Bureau of Standards Research Paper No. 170, and in Bureau of Mines Technical Papers Nos. 158 and 539.

When a chemical analysis of the gas mixture is available, an approximate method applying the law of corresponding states may be used. At any given percentage of critical temperature and critical pressures many gases have approximately equal values for PV/RT, P being absolute pressure, V volume, R a constant, and T absolute temperature. Actually between methane, ethylene, ethane, propane, isopropane, n.-pentane, hexane, cyclohexane, heptane and butane there is a maximum difference of about .03 in the value of PV/RT at temperatures below critical and at pressures up to 4 times critical. The greater deviations from 1.0 are in general, on the compounds of lower molecular weight. The data on ethylene falls about the middle of the group. Oddly, the values for water vapor as shown in Figure 13 very closely approach those for ethylene.

In using these data, reduced temperature and reduced pressure are calculated. To determine reduced temperature and reduced pressure, the pseudo-critical temperature of the mixture must first be determined. The pseudo-critical temperature is the mol average critical temperature of the constituents. Pseudo-critical pressure is the mol average critical pressure of the constituents. Reduced temperature and pressure are these values divided into flowing temperature and pressure respectively.

From the values of reduced temperature and reduced pressure, a value of PV/RT may be read from a family of curves.

The correction for supercompressibility at flowing conditions is equal to the square root of the reciprocal of this value.

For most natural gases and refinery gases there is a rough relationship between specific gravity and pseudo-critical temperature and pressure. This has made possible the development of several empirical methods of determining supercompressibility from data on specific gravity, temperature and pressure. The simplest of these, the direct method using formulae or tables developed by the California Natural Gasoline Association, is applicable only to pressures well below critical. Another method, applicable to higher pressures, involves the intermediate steps of estimating pseudo-critical temperature and pressure from the specific-gravity data, calculating reduced temperature and reduced pressure, and then reading values of PV/RT from the curves.

Viscosity

Coefficients of primary devices depend on the ratio of inertia forces to friction forces. As the friction or viscous forces become predominant, the importance of this relationship becomes more pronounced. One of the best known criteria for coordinating viscous flow is Reynolds number, R_D or R_d. (Velocity times diameter times density divided by absolute viscosity, all expressed in the same system of units.) Sometimes it is based upon conditions upstream from the orifice, more often on conditions in the orifice or throat of the primary device.

E. L. Hodgson used rate of flow in grams or

pounds per second divided by diameter times absolute viscosity in the same system of units. This criterion is equal to $(\pi/4) \times$ Reynolds number. Many other criteria have been used to express the ratio of inertia to friction forces.

Flange coefficients for non-viscous flow, as published by the ASME plot a straight line against the reciprocal of any of these criteria. Those for vena contracta taps plot a straight line against the square root of the reciprocal of the Reynolds number. To calculate an accurate Reynolds number, the actual rate of flow must be known. In laboratory test work, this is no inconvenience, because actual flows are determined from weight or other check readings. In commercial work, however, actual rate of flow is the unknown and the only purpose in calculating Reynolds number is to ascertain rate of flow from the meter readings. Hence there is a need for a more convenient criterion.

If a value of discharge coefficient is assumed for each ratio of orifice to pipe diameter, correction factors for each ratio may be plotted. If these values are plotted as the ordinate against a constant times Reynolds number divided by the correction factor, direct calculations may be made from the meter readings in a single calculation.

The curves are prepared as follows: At a Reynolds number of 3000 on a .55 d/D ratio the correction factor to be applied to the assumed non-viscous coefficient (ratio of actual value to assumed value) is 1.1125. The factor .00408 times Reynolds number divided by this correction factor is equal to

$$\frac{.00408 \times 3000}{1.1125} = 11.0.$$

This may be shown* to be equal to Ind. G.P.H. (i.e. rate of flow in gallons per hour at flowing tem-

*$\text{G.P.H.} = \frac{3600\,V}{2.54} \times \frac{\pi}{4}\left(\frac{D}{2.54}\right)^2 \times \frac{1}{231}$

$d = \frac{D}{2.54}$

$t_a = 465\,\frac{\mu}{\rho}$

$\frac{\text{G.P.H.}}{dt_a} = \frac{3600 \times \mu \times 2.54\ R_d}{2.54 \times 4 \times 2.54^2 \times 231 \times 465} = .00408\ R_d$

G.P.H. = Ind. G.P.H. × Correction Factor

$\frac{\text{Ind. G.P.H.}}{dt_a} = \frac{.00408\ R_d}{\text{correction factor}}$

G.P.H. = rate of flow, gallons per hour at flowing temperature.
d = bore of primary device in inches.
t_a = unit of viscosity, equal to 4.65 × centistokes. (t_a units are approximately equal to Saybolt Seconds Universal at viscosities above 190 S.S.U.).
V = velocity in centimeters per second.
D = bore of primary device in centimeters.
ρ = density of flowing fluid in grams per cubic centimeter.
μ = absolute viscosity in poises.

R_d = Reynolds number $= \frac{VD\rho}{\mu}$

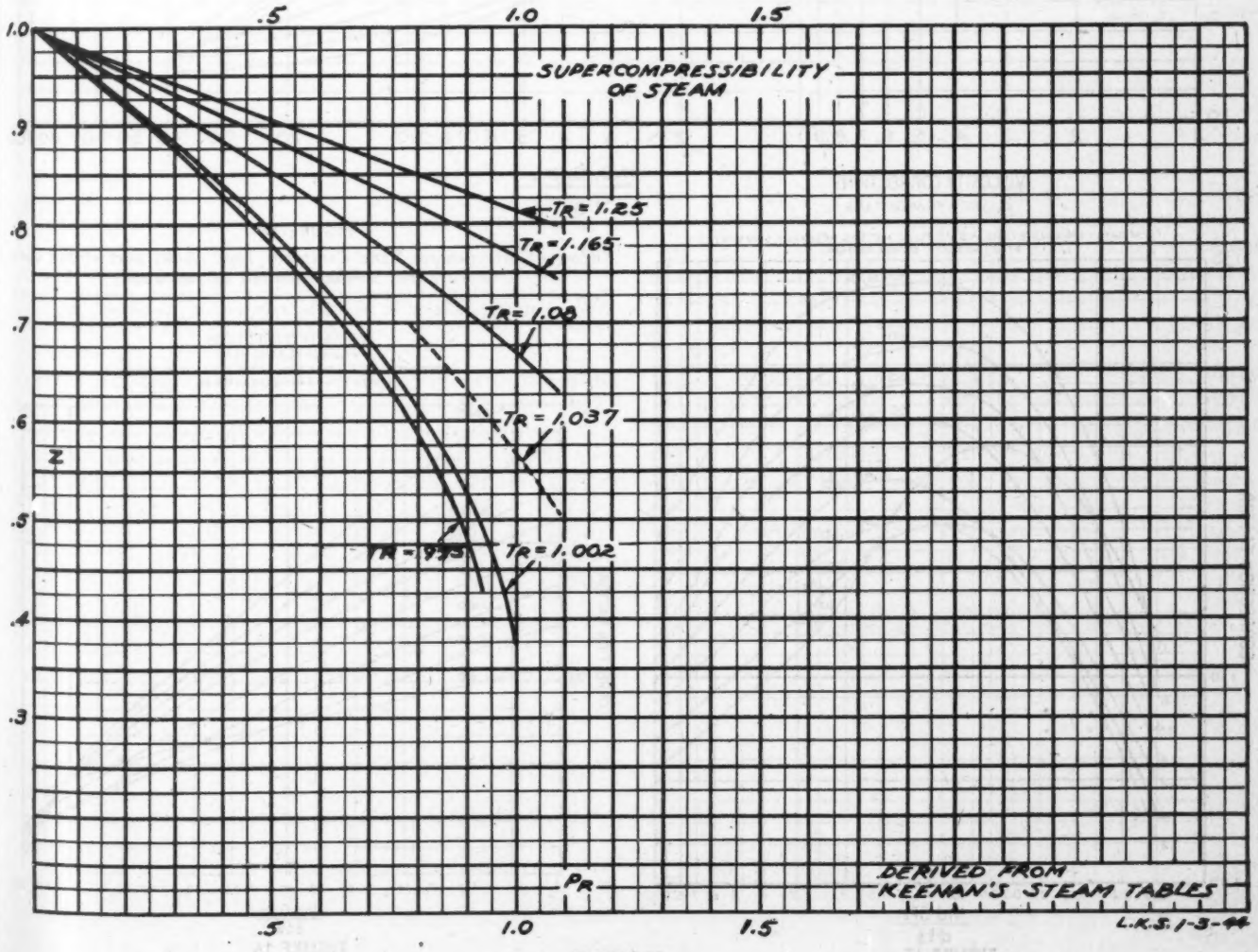


FIGURE 13
Supercompressibility of Steam
Derived from Keenan's Steam Tables.

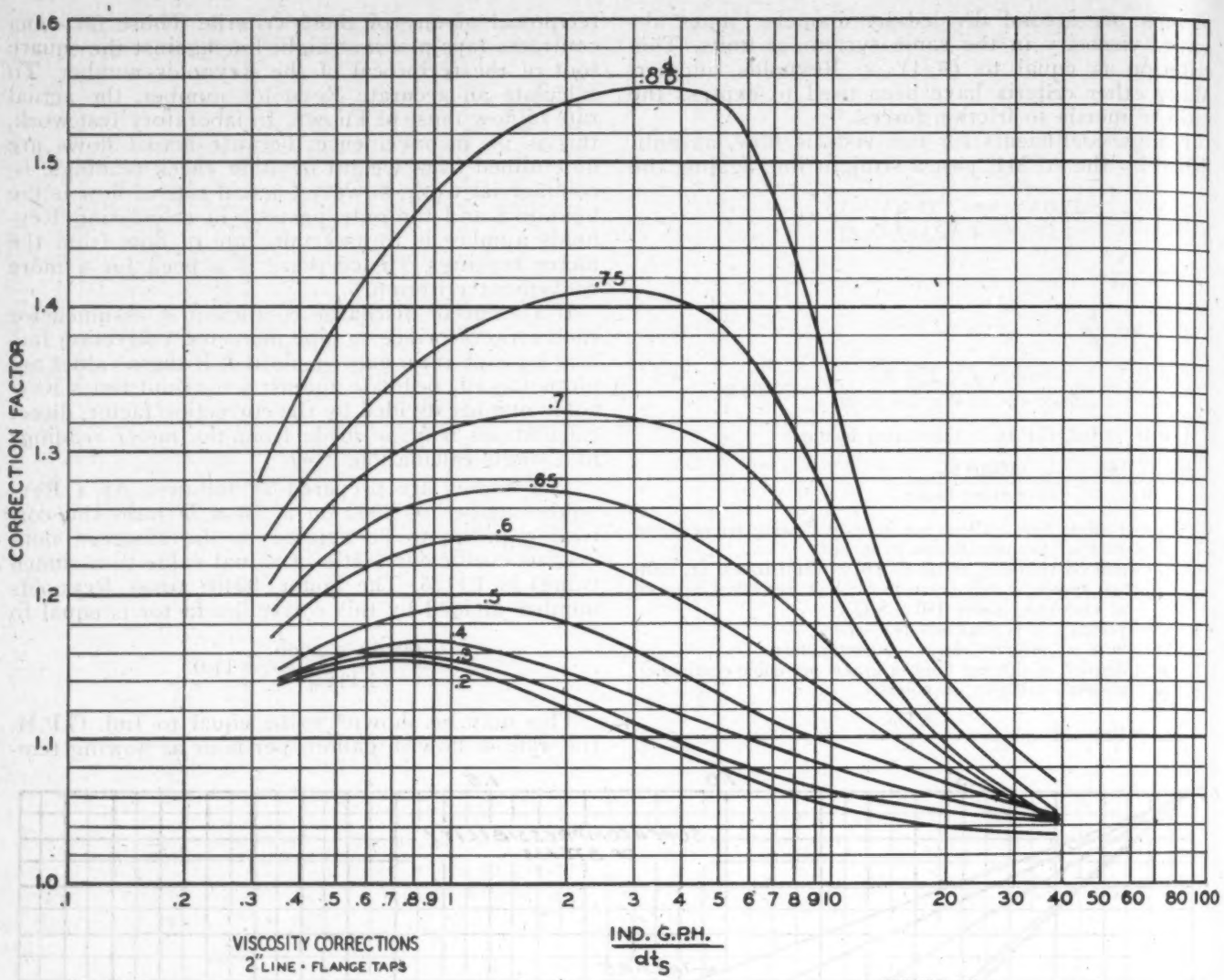


FIGURE 14

Viscosity Correction for Vena Contracta Taps. Shows part of the data of Tuve and Sprenkle plotted on this basis.

Derived from "Orifice Discharge Coefficients for Viscous Liquids," Figure 1, by G. L. Tuve and R. E. Sprengle, Instruments, November, 1933.

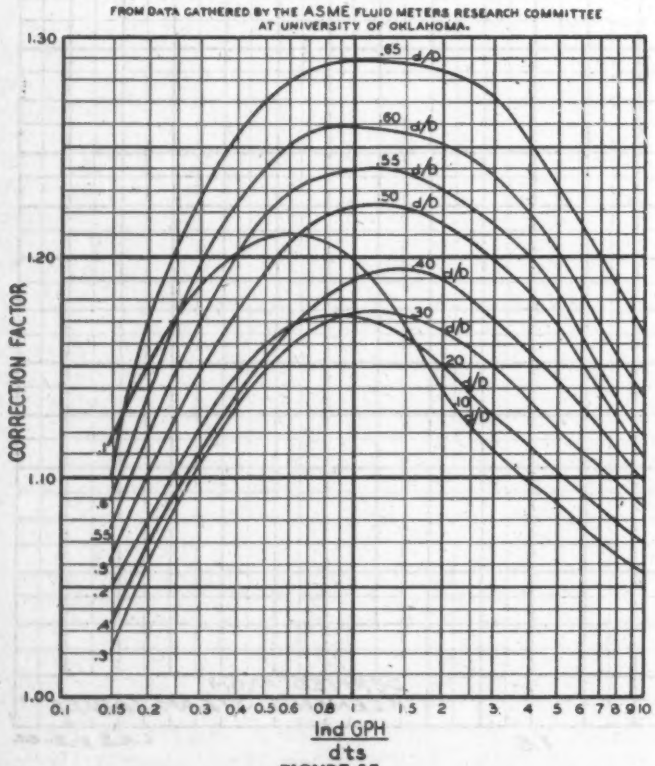


FIGURE 15

Viscosity Corrections—2-inch Line

From Data gathered by the A.S.M.E. Fluid Meters Research Committee at University of Oklahoma.

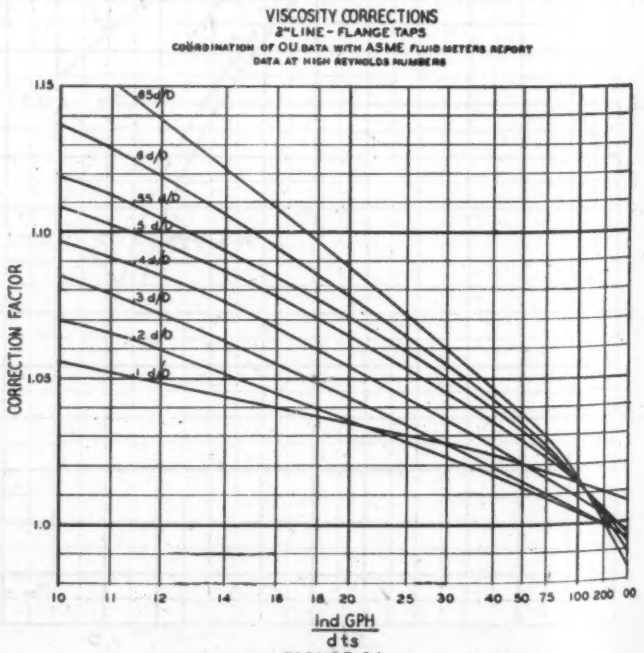


FIGURE 16

Viscosity Corrections—Coordination of OU Data

Co-ordination of OU Data with A.S.M.E. Fluid Meters Report Data at High Reynolds Numbers.

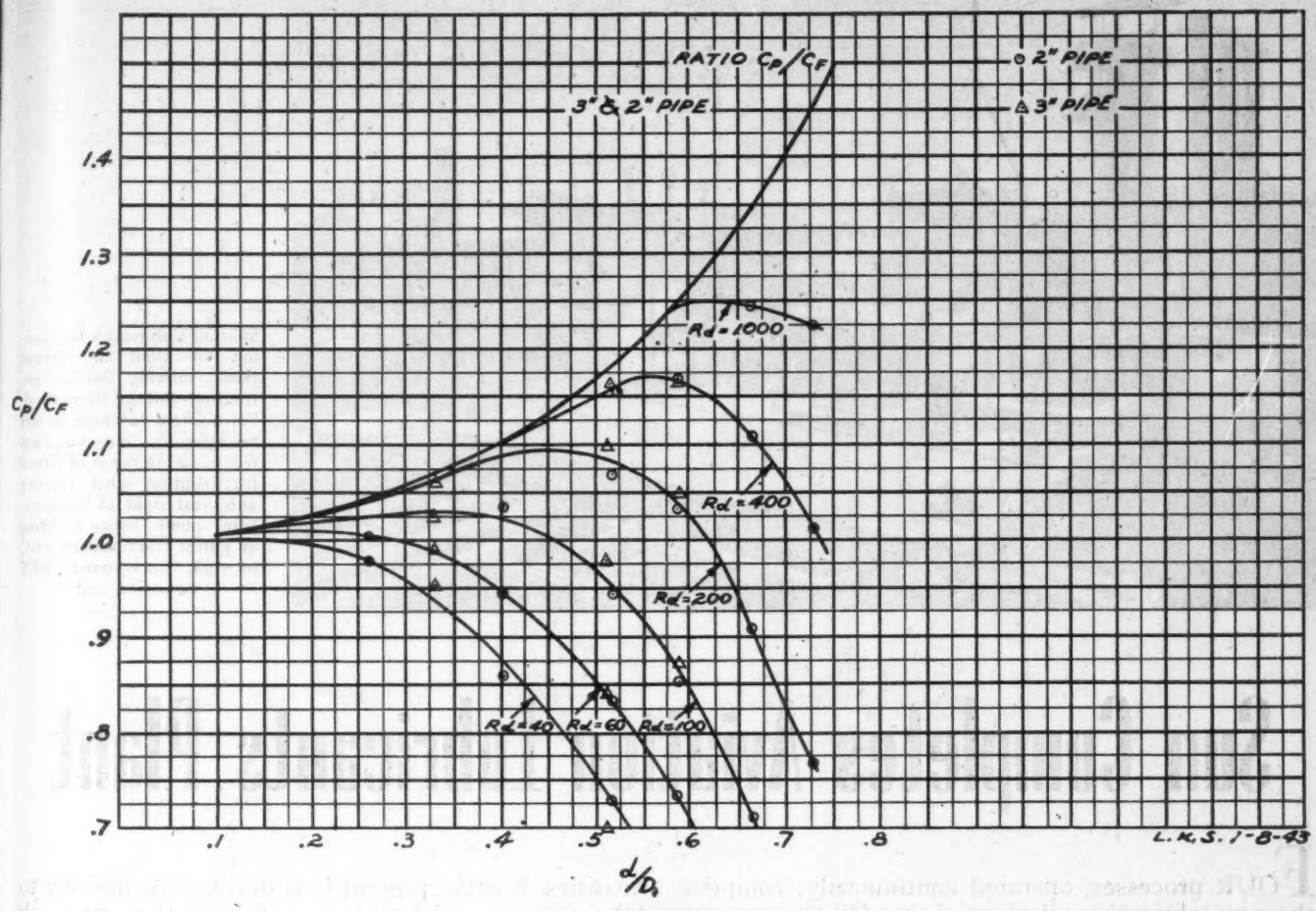


FIGURE 17
Ratio of Pipe Tap to Flange Tap Coefficient

perature computed from the assumed non-viscous coefficient of discharge) divided by the product of d (diameter of orifice in inches), times t_s (units of viscosity equal to 4.65 × viscosity in centistokes). Plot a correction factor of 1.1125 at a value of Ind. G.P.H./d t_s of 11.0, and proceed in a similar manner for other points on the curve.

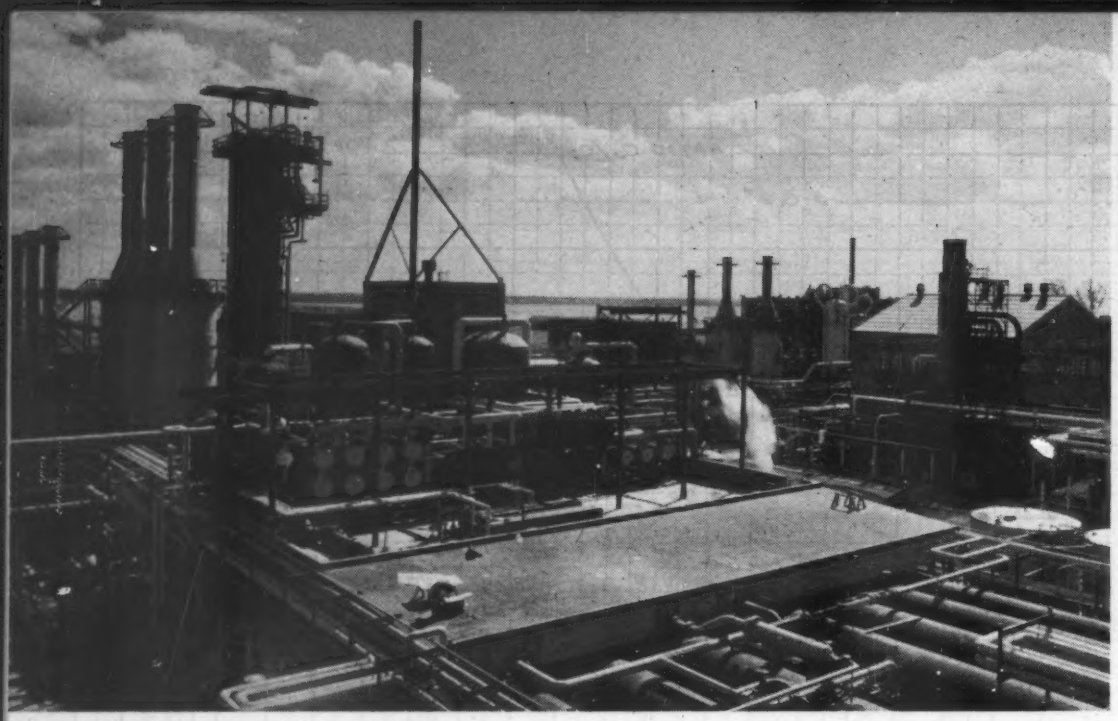
If, in a commercial measurement problem, the flow, computed from the assumed nonviscous flow coefficient equals 2501 G.P.H., the diameter of the orifice is 1.137 inches in a 2.067-inch line, and the value of $t_s = 200$, Ind. G.P.H./d $t_s = 2502/1.137 \times 200 =$ 11.00. The correction factor is then equal to 1.1125 and the actual rate of flow = 2783 G.P.H. Reynolds number is therefore $2783/1.137 \times 200 \times .00408 =$ 3000, which checks the value on which the correction factor was based.

The following curves are preliminary analyses of data gathered by ASME from 6694 tests on commercial pipe at the University of Oklahoma. Final preparation for presentation in the form of a technical paper has not been completed, but the preliminary analysis is presented here with the thought of making this information available to industry as soon as possible.

The correction factors, read from Figures 15 or 16, multiplied by the following assumed nonviscous discharge coefficients, give true values of discharge coefficient including velocity of approach.

d/D	E*	d/D	E*	d/D	E*
.1	.5990	.4	.6110	.6	.6580
.2	.6004	.5	.6271	.65	.6815
.3	.6035	.55	.6403	....	....

Calculated from $E = .598 + .01\ d/D + .00001947\ (10d/D)^{4.425}$
* E = assumed non-viscous discharge coefficient, including velocity of approach.



Sun Oil Company's lubricating oil plant at Marcus Hook, showing Duo-Sol extraction unit in foreground; Petro-Chem furnaces in left background; the vacuum fractionating tower of Filtrol fractionation and re-run unit, just right of furnaces; filter pump house building of Filtrol fractionation unit; in right background, MEK dewaxing unit.

Sun Completes Aviation Lubricants Plant

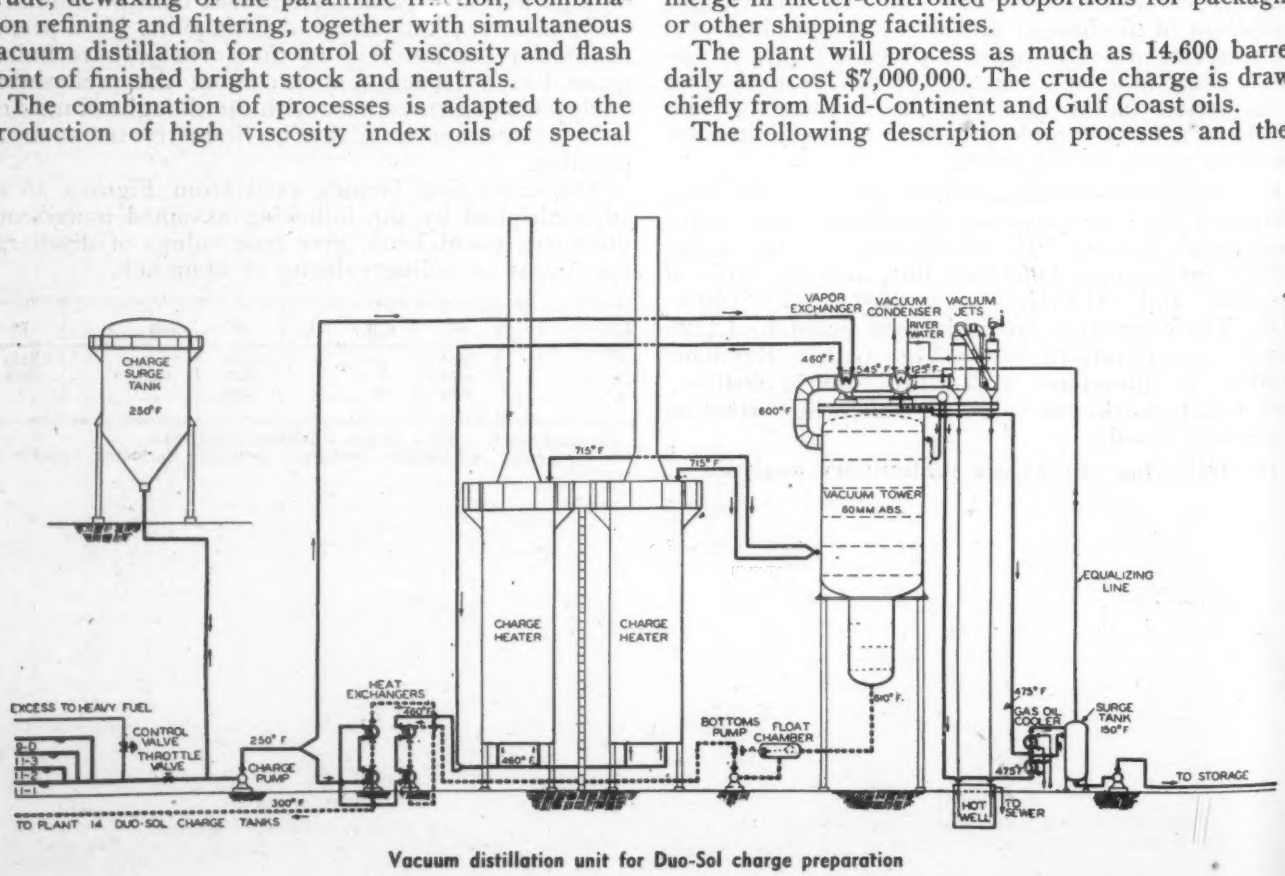
FOUR processes, operated continuously, comprise the new lubricating-oil plant of Sun Oil Company at Marcus Hook, Pennsylvania.

The units provide stock preparation by vacuum distillation, solvent extraction of the vacuum reduced crude, dewaxing of the paraffinic fraction, combination refining and filtering, together with simultaneous vacuum distillation for control of viscosity and flash point of finished bright stock and neutrals.

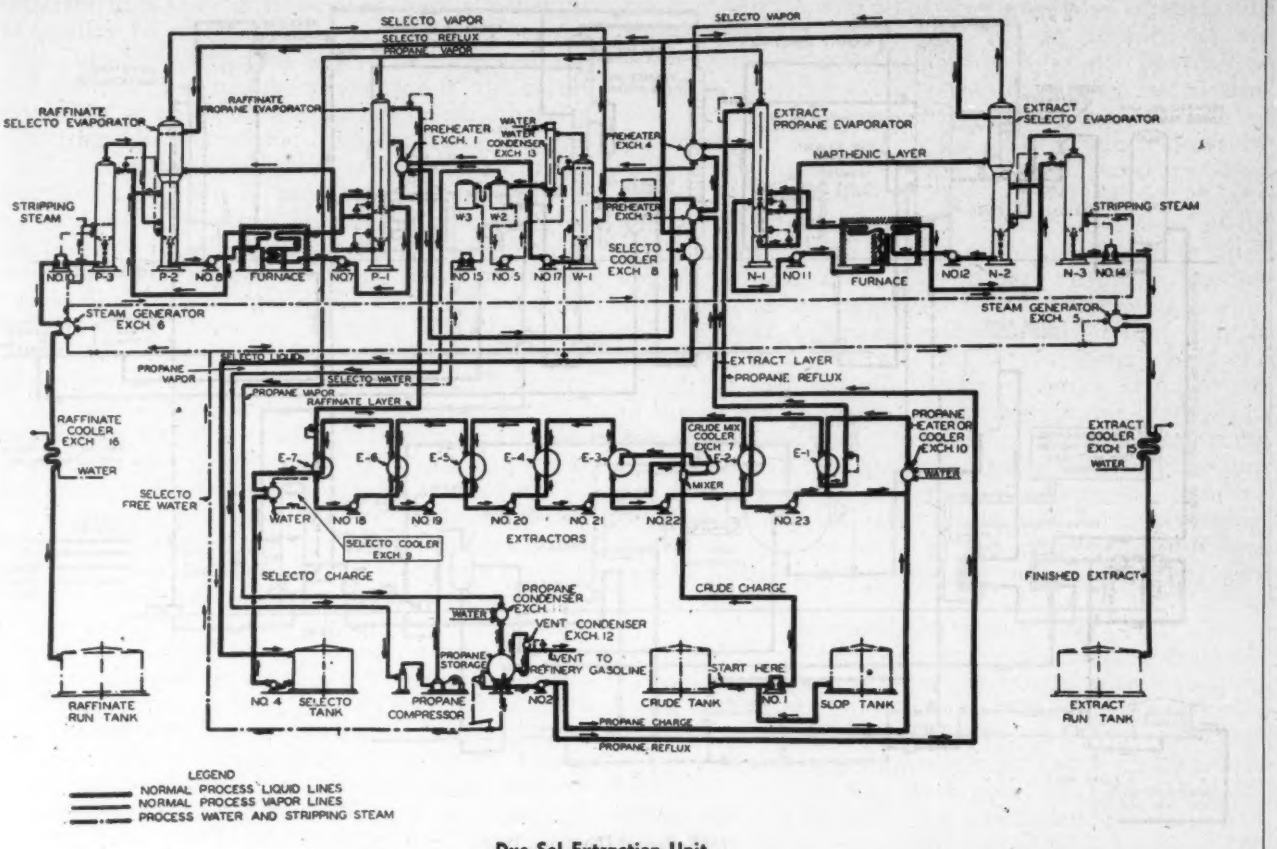
The combination of processes is adapted to the production of high viscosity index oils of special qualities. For the present it is devoted exclusively to lubricants essential to the conduct of the war, such as aviation-grade and heavy-duty oils. Finished oils are completed in the blending unit, which is capable of handling as many as five distinct streams, which merge in meter-controlled proportions for packaging or other shipping facilities.

The plant will process as much as 14,600 barrels daily and cost $7,000,000. The crude charge is drawn chiefly from Mid-Continent and Gulf Coast oils.

The following description of processes and their



Vacuum distillation unit for Duo-Sol charge preparation

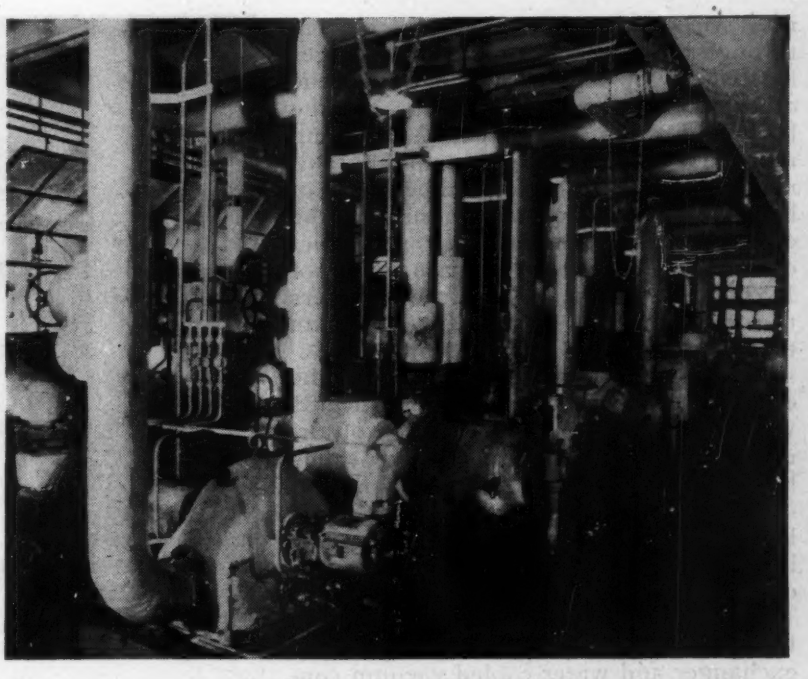


Duo-Sol Extraction Unit

operation was prepared as a set of complete notes by Dr. Paul D. Barton of the Sun Oil Company staff.

"The unit is designed for extreme flexibility in type of stock charged, and range of viscosity, viscosity index, flash, fire, pour-point and other pertinent qualities. In changing from one stock to another or from one grade of product to another grade on the same stock, continuity of operation is obtained by the means of large capacity surge tanks between units. That is, the dewaxing plant may be processing an oil at the end of a run for several days before it is necessary to accept a different stock being produced by the solvent extraction unit. Means also are provided in each operating unit for rejecting off-specification products without interfering with the overall plant continuity.

"A feature of the plant as a whole is the convenient arrangement of the various operating units which are all operated in conjunction under the same supervision. A control laboratory for simple routine tests is located within the plant, and an intercommunication system makes coordination a very simple process.

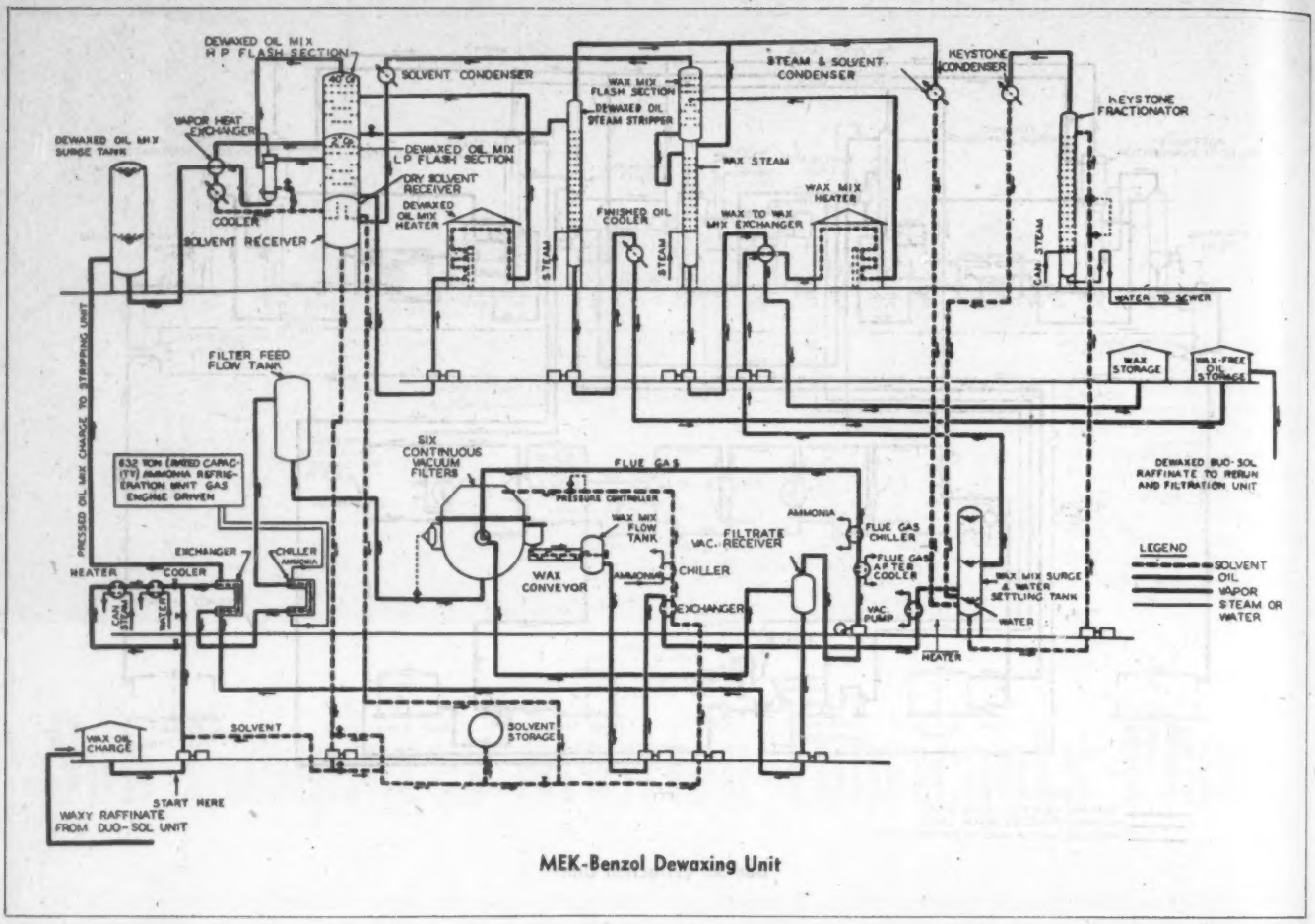


Hot-Oil Pump Room of Duo-Sol Unit

Vacuum Distillation Charge Unit

"The charge stock consists of tower bottoms from four crude units, it being possible to take any combination of these units depending upon the charge rate desired. When making aircraft oil, it may be necessary to run all four units in order to obtain the charging capacity of 14,600 barrels per stream day of reduced crude. The bottoms from those sources come from exchangers at a temperature of about 250° F. and because of fluctuation in rate due to bottom tower level-control operation, it is necessary to provide a surge tank ahead of the vacuum-unit charge pump.

"The charging-pump-discharge stream is divided



MEK-Benzol Dewaxing Unit

into two portions, one being conducted through the tubes of the vapor exchanger located on top of the vacuum tower, the other passing through the tubes of the bottoms heat exchangers, the split being manually controlled to obtain approximately the same outlet temperature of both portions. The temperature of the charge is raised from an exchanger outlet of about 460° F. to a furnace outlet of 715° F., at which temperature it enters the vacuum flash tower. The vacuum tower is operated for the retention of desired lubricating-oil fractions and the elimination of gasoil (and light lubricants when operating for the production of aircraft oils), the flash point of the bottoms being controlled by the introduction of a small quantity of stripping steam. The bottoms pass through the shells of the heat exchangers and coolers and are conducted to the Duo-Sol unit charge tanks. The overhead vapors from the vacuum tower pass in series through the vapor exchanger and water-cooled vacuum condenser. The uncondensed steam and uncondensed gases and vapors are eliminated through the combination barometric condensers and vacuum jets. Condensed gasoil is withdrawn in two streams, one from the vapor exchanger, which also supplies reflux, the other from the vacuum condenser. These streams are cooled separately and are composited in a surge tank. When operating for the production of aircraft oils, the overhead distillate is too heavy to be classed as fresh gasoil, being considered suitable only for heavy-oil cracking plant charge. It should be pointed out that a side stream can be taken from this tower, making available a fresh gasoil product overhead; when operating for the production of motor oils, the overhead product will meet fresh gasoil sepcifications.

Ammonia Compressors of MEK Dewaxing Unit

"Reduced crude from vacuum tower operation is accumulated and stored hot (200-225° F.) in two

24,000-barrel tanks. It is important that a constant charge quality be maintained to get the best results from the Duo-Sol extraction unit. The object of the Duo-Sol treatment is to take advantage of the selective solubility of two non-miscible solvents, thereby concentrating the paraffinic hydrocarbons in one layer and the naphthenic hydrocarbons in the other. The paraffinic solvent is propane; the naphthenic solvent is called 'Selecto.' Selecto is composed of varying proportions of phenol and cresol, depending somewhat upon the type of oil being treated and the final result desired. The relatively large difference in gravity (Selecto 1.05 sp. gr., Propane .509) between the two solvents facilitates the operation which is carried out in a series of extractors in which intimate mixing is followed by a low-velocity separation.

"In operation, the charge oil is introduced at a controlled temperature (100° to 130° F.) and at a pressure sufficient to keep the contents of the system in the liquid phase (approximately 300 pounds gauge) to a mixer located between the second and third extractors where it joins with the propane charge stream (which has already been contacted counter-current to the effluent extract stream in extractors 1 and 2) and with the Selecto stream from extractor 4 (the Selecto having been charged to extractor 7 counter-current to the effluent propane or raffinate layer). It is thus seen that the two effluent streams come from opposite ends of the series of extractors, the extract being washed by fresh propane, the raffinate being washed by fresh Selecto. The proportions of solvents to charge are from 4-6:1 for Selecto and 2-3:1 for propane.

"The two solvents not being completely immiscible, it is necessary to provide for the recovery of dissolved propane from the extract layer and to recover dissolved Selecto from the raffinate layer. Thus, it will be seen that the recovery system consists of two complete sets of distillation and stripping towers, although products are finally combined where possible, one set of propane condensers and one set of Selecto coolers serving both recovery units. Selecto is stripped out of both extract and raffinate at low pressure with direct steam, steam being condensed and the water fed to the steam generator for the production of process steam, thus minimizing the loss of solvent.

"The extract containing a concentration of naphthenic oils and asphaltic materials contained in the charge is continuously cut back with a gasoil or a similar low viscosity product to obtain a Bunker C fuel oil specification. The raffinate containing a concentration of paraffinic oils and most of the waxes present in the charge is ready for further processing in the dewaxing unit.

MEK-Benzol Dewaxing Unit

"The MEK-Benzol Dewaxing Process utilizes the composite properties of mixtures of benzol and toluol with a ketone. Methyl-ethyl-ketone (MEK) is considered superior to acetone. By varying the proportions of the components of the solvent the miscibility and the wax solubility at different dilution ratios (with respect to oil and solvent) may be controlled.

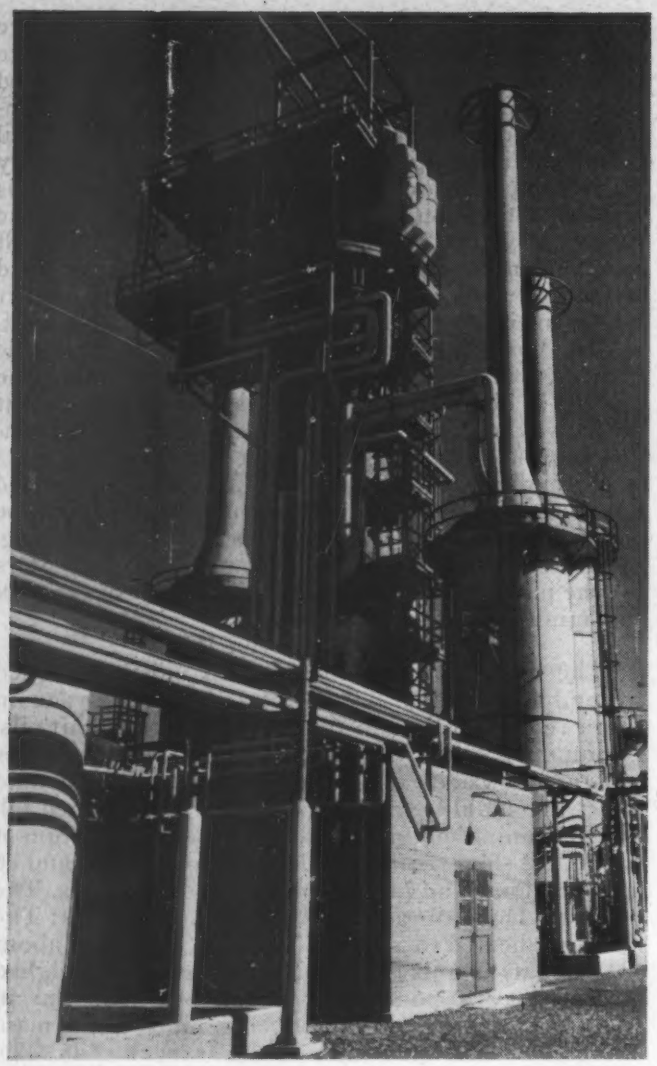
"In operation, the waxy Duo-Sol raffinate is mixed in predetermined proportions (approximately 3 to 1, solvent to oil) with a solvent of the optimum composition (with respect to MEK, benzol and toluol), the mixture being cooled first through water-cooled tubulars, next through scraped-surface exchangers against the cold filtrate, and finally to the desired temperature (approximately minus 20° F.) in scraped-surface chillers using ammonia as a refrigerant. The chilled solution containing the crystallized wax is fed continuously to the rotary drum filters, the wax-free oil remaining in solution in the filtrate which flows by differential pressure to the vacuum receivers. This filtrate is then pumped through exchangers to the recovery system where the solvents are distilled off and condensed, the filtered oil being finally stripped free of solvent, cooled, and stored ready for further treatment in the rerun and Filtrol fractionation unit.

"The wax contains considerable solvent and is processed in a separate recovery system where the solvent is distilled off, the traces being stripped out of the wax with steam. The water obtained from condensing the stripping steam from both recovery units is accumulated and the dissolved MEK is fractionated out of the water to prevent solvent loss. It should be pointed out that the plant is arranged for a 'repulping' operation upon the wax as it comes from the filters for the purpose of reducing the oil content of the wax to a minimum.

Dewaxed Oil Rerun Unit

"The Filtrol fractionation process unit is designed to combine a contact filtration process with a vacuum tower rerun distillation. When producing aircraft oils, the function of the vacuum tower is to remove traces of light oils and decomposition products which would affect the stability and flash point of the finished oil. When running motor oils, it has the added function of producing side stream distillates of SAE 10, 20 and 30 specifications, and filtered bright stock bottoms. The dewaxed Duo-Sol raffinate is treated as follows: The charge is heated to about 265° F. and a portion, about 15 percent, is mixed continuously with a weighed amount (say 10 pounds per barrel) of Filtrol clay in a slurry mix tank, this slurry being added to the main charge stream at the inlet of the furnace coils. The charge containing Filtrol clay is raised to the proper temperature in the furnace before entering the vacuum flash tower. Bottoms from the tower containing the fine clay in suspension, is picked up by the filter-charge pump from the filter surge tank and is fed continuously to a rotary drum pre-coat filter at a temperature of 300 to 400° F. The hot clay-free filtrate flows by differential pressure to the vacuum filtrate receiver from where it is pumped through the product cooler to storage. The side streams require no further treatment except cooling before running to storage. A considerable amount of super-heated steam is used in the vacuum tower and passes along with uncondensed oil vapors into the vacuum condensers and finally into the vacuum jets and barometric condensers. Reflux is returned by gravity and the overhead condensed gasoil product, without further cooling, is pumped to storage.

"The plant includes equipment for fresh clay unloading, storage and handling; for the disposal of spent clay; and for the special periodic pre-coating operation required to keep the filter operating efficiently. The pre-coating operation consists of perodically depositing a layer approximately two inches thick of Filtercel (diatomaceous earth) upon the outer periphery of the rotary drum by producing a slurry with a light oil, heating the mixture, and operating the filter in a special circuit for building up the pre-coat cake upon the filter drum. The filtering surface thus prepared will last from a week to 10 days, the Filtrol clay being deposited on the outer



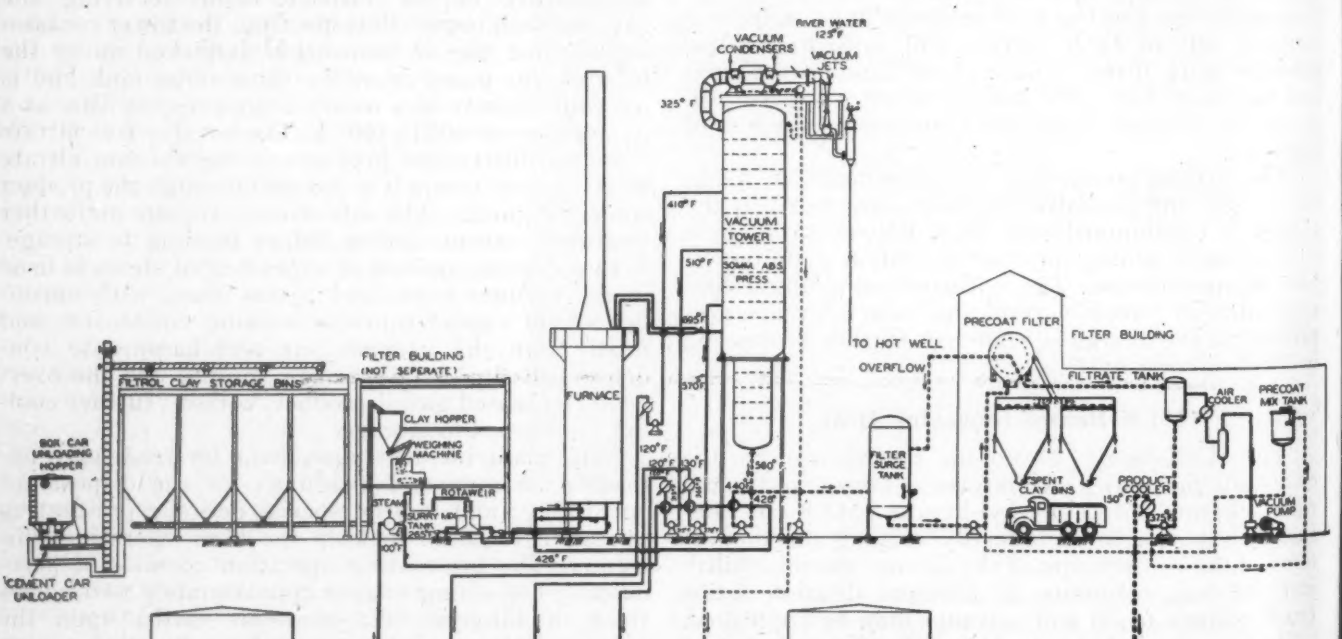
surface from which it is shaved by a long carefully-adjusted knife which gradually cuts away the precoat layer until it is necessary to replace it as described above.

"A distinctive feature of this unit is the combination of the refining action of Super-Filtrol together with a distillation of the lower-viscosity lubricants. In operation the clay remains in the bottom fraction of the vacuum tower but retains high molecular weight color bodies and decomposition products which would otherwise appear to some extent with the distillates. The use of the Super-Filtrol clay at elevated temperature utilizes the highest possible efficiency of the filtration process which as compared to conventional percolation type filtration effects a very material saving in handling, disposal of spent clay and loss of absorbed oil.

Blending and Packaging Unit

"The finished oils from the preceding unit are accumulated in a relatively small number of storage tanks. The finished specification lubricants are then other components as may be desired by means of made up continuously from the basic refined oils and other components as may be desired by means of mechanical blending units capable of handling as many as five distinct streams which merge in meter-controlled proportions in an homogenizer which in turn discharges the finished oil to packages or other shipping containers. Blending units of different capacities are provided and the blending operation as a whole can handle two different specification finished oils simultaneously in a range from a few barrels of the blend up to a tank car or barge load without intermediate storage."

Pump house, fractionating tower and furnaces of the Filtrol fractionating and rerun unit. Furnaces for the Duo-Sol unit are shown in the background and the rundown tank for the Filtrol unit is seen in the left foreground.



Dewaxed oil rerun unit of Filtrol Fractionation Process

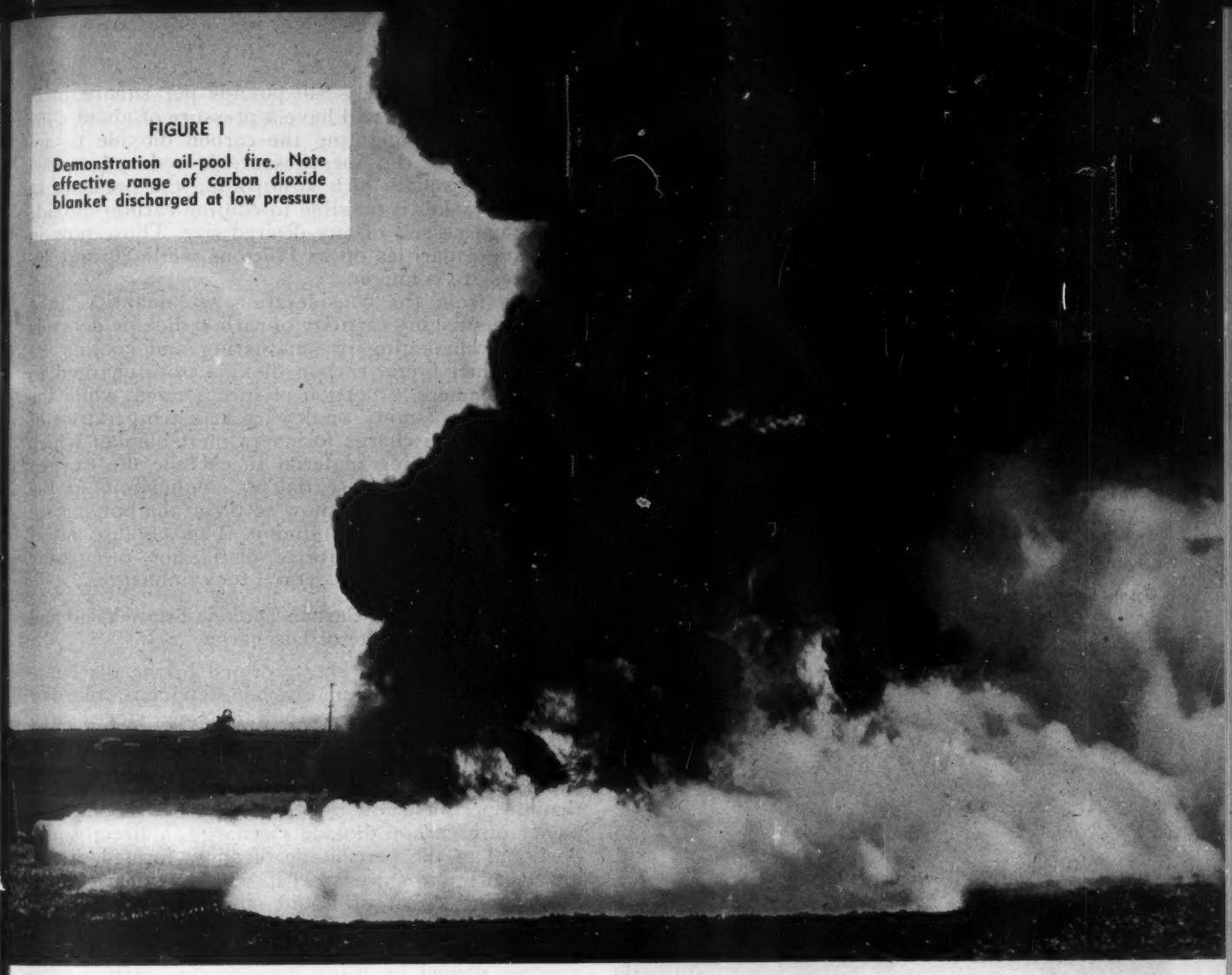


FIGURE 1

Demonstration oil-pool fire. Note effective range of carbon dioxide blanket discharged at low pressure

How Carbon Dioxide Conquers Fire

H. V. WILLIAMSON
Cardox Corporation

DEVELOPMENT in the application of carbon dioxide to fire extinguishment have been unusually rapid during the last few years. The small emergency extinguisher has grown into a giant, capable of controlling and extinguishing even large airplane-crash fires, which are basically gasoline and oil fires in a highly specialized form. This kind of performance foreshadows the increasingly important part that carbon dioxide will play in the control of other types of petroleum fires.

As a fire-extinguishing medium, carbon dioxide has certain definite and important advantages over water, foam, and other used agents. For instance, it will extinguish all types of petroleum fires, including even running fires involving highly volatile products. Furthermore, its action is extremely rapid and it will not contaminate or damage unburned material. In spite of this, it has until recently been given only minor consideration in petroleum-fire protection. This attitude was the natural result of the fact that the supply of carbon dioxide contained in available fire extinguishers was simply too limited for anything but very small fires.

This problem of carbon dioxide availability has been satisfactorily solved by the use of low-pressure liquid carbon dioxide. Instead of pounds, it is now possible to make tons of carbon dioxide available for extinguishing large fires. Obviously, the size fire that can be extinguished with liquid carbon dioxide has increased many fold.

The vapor pressure of liquid carbon dioxide depends upon its temperature; that is, the pressure goes up and down with the temperature. A normally filled cylinder of carbon dioxide at 70° F. will have a pres-

FIGURE 2
Gasoline spray hazard. Gasoline is being forced from leaking flange at the rate of ten gallons per minute.

FIGURE 3
Ignited, gasoline was allowed to reach high intensity.

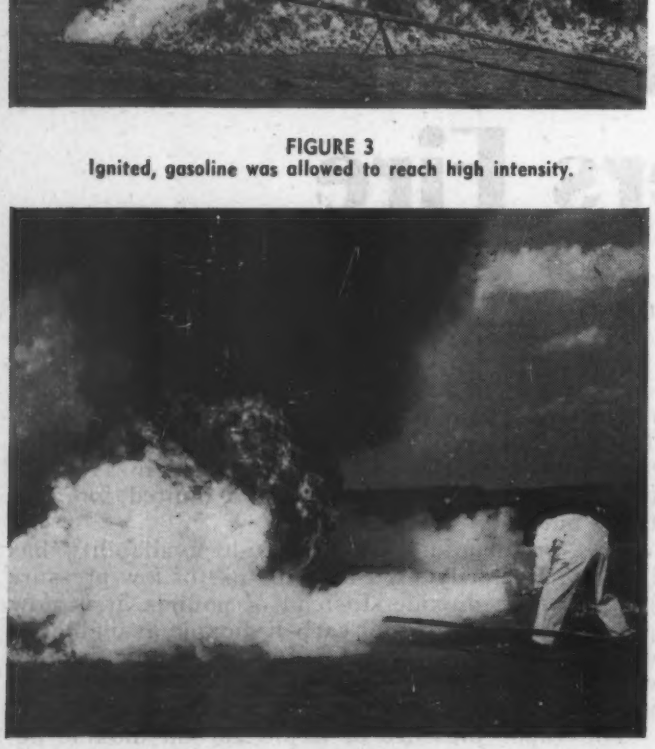


FIGURE 4
Fire is attacked with hose line nozzle directing carbon dioxide at its heart at rate of 700 gallons per minute.

sure of approximately 840 pounds per square inch, while at 100° F. it will have a pressure of about 1460 pounds. By refrigerating the carbon dioxide to approximately 0° F., the pressure is reduced to 300 pounds per square inch. Controlling the pressure in this way makes it possible to confine carbon dioxide in storage vessels of any desired size. Those now in use have capacities up to 125 tons while 20 and 30-ton sizes are common.

Aside from the consideration of "quantity," the fire extinguishing capacity of carbon dioxide depends upon its blanketing or smothering and cooling effects. When liquid carbon dioxide is discharged to the atmosphere, a portion of it vaporizes, while the rest turns to "snow" or dry ice at a temperature of 110° F. The discharge forms an inert blanket which covers the burning material to exclude the oxygen of the air which is essential for combustion. At the same time, particles of snow settle on the hot surface and absorb heat in subliming. This cooling effect quickly reduces the rate of distillation of volatile vapors which also are essential for combustion.

Importance of High Carbon Dioxide Snow Yield and Rate of Discharge

The percentage of snow formed in the discharge is greater when the liquid carbon dioxide is cold. For instance, when liquid carbon dioxide, stored at a normal summer temperature of 80° F., is discharged to the atmosphere, only 24 per cent is converted to snow, whereas liquid released at 0° F. produces more than 46 percent snow. Since the effective cooling capacity of a carbon dioxide discharge is directly proportional to the percentage of snow formed, it follows that liquid stored a 0° F. will have nearly twice the cooling effect of liquid stored in cylinders at 80° F.

The increased cooling effect is not the only advantage gained by using low-pressure carbon dioxide. Solid carbon dioxide, or snow, is about five hundred times as dense as the vapor and can, therefore, be projected forward through a much greater distance without being effected by air turbulence. It is like throwing pebbles into the wind as compared to feathers. For this reason, the use of low-pressure liquid carbon dioxide results in a more dense discharge stream which can be effectively projected

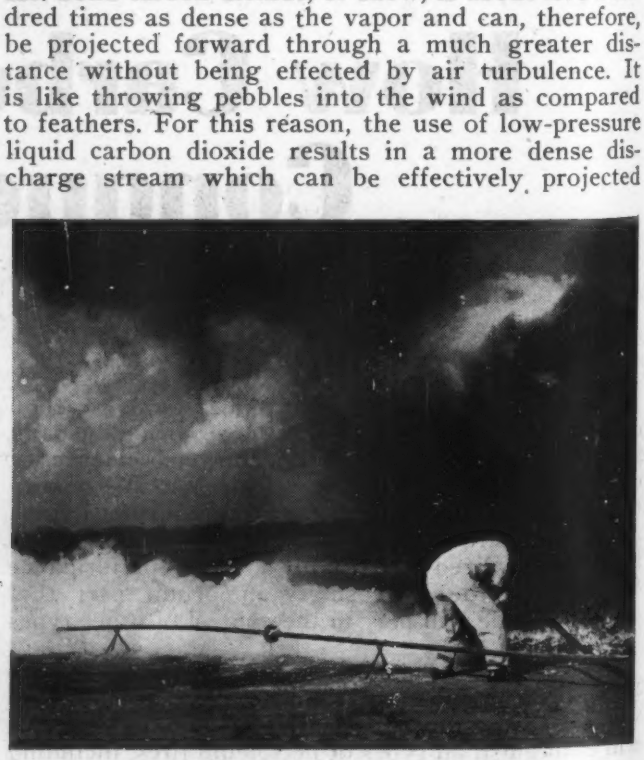


FIGURE 5
Main fire out, blanket of carbon dioxide prevents reflash while remaining small ground fire is quickly extinguished.

through a greater distance. This extra range or reach is of the utmost importance when fighting outdoor fires.

The discharge capacity of the nozzle used also has an important bearing on the discharge range and the size of fire that can be extinguished with carbon dioxide. One man can conveniently manipulate a 12-inch nozzle which has a discharge capacity of over 700 pounds of carbon dioxide per minute. This nozzle is fed by a 1½-inch hose line and will project the discharge effectively from 20 to 50 feet, depending upon the wind conditions. This relatively great range as well as the coverage afforded by the high discharge rate makes it possible for the operator to attack large fires without special equipment to protect him from the heat. This is an important point, as protective clothing may not be available. Even if it is available, time is lost in preparation and the operator is hampered by extra equipment.

A typical example of what can be accomplished with this nozzle and hose reel is illustrated in Figure 1, showing the extinguishment of a 16x30-foot pool fire containing quenching oil. In demonstration work, this fire is allowed to burn for one minute or more to reach a state of high intensity. The operator then attacks from the windward side and sweeps the fire out from one end to the other, maintaining a curtain of carbon dioxide between the fire and the part of the pool that has been extinguished. The extinguishment is completed in less than 15 seconds. Since the nozzle discharges at a rate of 700 pounds per minute, less than 175 pounds of carbon dioxide is used in the demonstration.

Extinguishment of Spraying Gasoline Fires

While oil-pool fires of the above type can be extinguished with the use of water in the form of fog, this is not possible when more volatile fuels are used, unless the fire is in a steel structure which will produce and retain large volumes of steam. The extinguishment of a particularly difficult hazard involving a spraying gasoline fire is illustrated in Figures 2, 3, 4 and 5. This hazard was set up to represent an ordinary pipe line which had sprung a leak at a flange due to a blown gasket. A pump was used to force high-test gasoline through the leaking flange at a rate of 10 gallons per minute, as illustrated in Figure 2. The gasoline was allowed to spray out for one minute to accumulate an excess on the ground before the fire was ignited. After ignition, the fire was allowed to burn long enough to reach its maximum intensity, as illustrated in Figure 3. The beginning of the attack on the heart of the fire is shown in Figure 4, while Figure 5 illustrates the final stages where only a small ground fire remained to be extinguished. It is to be noted that the hot gasoline is still spraying from the flange, while the rolling blanket of carbon dioxide prevents the remaining ground fire from causing a reflash. The full extinguishment, including the ground fire, was completed in approximately 20 seconds.

In actual practice, the job is not finished when the fire is extinguished. If a relatively large amount of exposed gasoline or other highly volatile material still remains, it must be protected against reignition until it can be removed. This can be accomplished by spreading a blanket of foam over the inflammable surfaces immediately after the fire has been extinguished.

As a matter of fact, where fires extend over such an area that they cannot be snuffed out in a few seconds with carbon dioxide, it is desirable to follow up the carbon dioxide discharge with foam so that areas which have been extinguished will be protected against possible reignition. The extinguishing action of carbon dioxide is extremely rapid, but the protective blanket it forms is soon dissipated by the wind. Foam, on the other hand, works raher slowly, even on open pool fires, and will not extinguish spray fires involving volatile fuels, but it does provide relatively lasting protection against reignition. Furthermore, a blanket thick enough for protection purposes can be applied very quickly once the fire has been

FIGURE 6
Truck using carbon dioxide supplemented by foam put out a simulated airplane-crash fire in two minutes.

extinguished. It takes a thick layer of foam to extinguish a fire whereas a relatively thin layer will serve to prevent reignition.

Application of Low-Pressure Carbon Dioxide to Large Fires

The same general principles used in extinguishing small fires are also applicable to much larger conflagrations. The only difference is that more applicators must be used and it is desirable to have at least one nozzle of larger capacity mounted on a mobile unit and equipped with motorized control. Equipment of this type is represented by the Cardox Airport Fire Truck which is shown attacking a large gasoline fire in Figure 6. The large cab-controlled boon nozzle, which has a discharge capacity of 2500 pounds of carbon dioxide per minute, is very effective in knocking down the main part of the fire so that playpipe operators can approach without special discomfort to extinguish the edges.

The fire shown in Figure 6 was fed by over 400 gallons of high-test gasoline distributed in a manner designed to create a very difficult situation. Aproximately half of the gasoline was spilled on the ground, while the rest was put in drums and allowed to flow out through 1-inch valves so that 5 separate running fires were involved. The entire fire covered an area of over 1000 square feet. The complete extinguishment was effected in approximately 2 minutes with the expenditure of about 5000 pounds of carbon dioxide supplemented by 200 gallons of foam solution. The foam was used to cover the gasoline-soaked areas so as to reduce the possibility of reignition, as discussed above.

The manner of attacking an airplane-crash fire is, of course, different than the technique that would be used on an ordinary petroleum fire. In an airplane fire, the first thought is to save any trapped passengers. Accordingly, the attack is directed to the cabin of the plane in spite of any condition which might suggest a different approach. This makes it possible to begin rescue operations within a matter of 10 or 15 seconds after reaching the fire, but it also tends to reduce the overall efficiency of extinguishment.

In the case of an ordinary petroleum fire, it is not necessary to rush in at breakneck speed and the attack can, therefore, be planned more carefully. The best results will be obtained by beginning the extinguishment on the windward side so as to sweep the fire downwind with the carbon dioxide discharge, while at the same time applying foam to the area under control.

Wide Range of Applications

The possible applications of low-pressure carbon dioxide to petroleum hazards are many and varied. These will run the gamut from mobile emergency fire equipment to automatic fixed fire extinguishing systems for particularly hazardous or important installations. In addition to actual fire extinguishing, there are many places where vaporous carbon dioxide can be used to prevent explosions which can be more serious than fire.

Carbon dioxide is particularly valuable in connection with mobile emergency fire equipment for quickly extinguishing fires in their early stages before they grow ino disastrous proportions. A truck has been designed to meet this need in a number of refineries and synthetic rubber plants. This truck has a capacity of three tons of liquid carbon dioxide and is equipped with two 100-foot hose lines feeding nozzles, each of which has a discharge rate of over 700 pounds per minue. By the use of quick-change couplings on the hose lines, trucks of this type can also be used as a mobile carbon dioxide source for fixed stand-pipe extinguishing systems.

For important, localized hazards, it has been found advantageous to install fixed systems using nozzles properly located to provide the most effective application. Pump houses, control rooms and outdoor transformers can be protected in this way. Such installations can be designed as stand-pipe systems to be supplied with carbon dioxide by the emergency trucks as mentioned above, or as complete systems with a constant source of carbon dioxide piped from a central storage tank. In the latter case, the system can be made completely automatic by the use of electric fire detectors and discharge conrol valves. Automatic timers usually are used in such systems to control the amount of carbon dioxide discharged into each particular hazard so that the reserve capacity of the storage tank will be available for continued fire protection. Low-pressure systems of this type are being used by most of the airplane motor manufacturers in this country for protecting their engine test cells.

Although carbon dioxide is not recommended for outdoor Class A fires involving wood, paper, and similar materials, the fact must not be overlooked that it can be used very advantageously in extinguishing indoor Class A fires by total flooding. It is only necessary to maintain a high carbon dioxide concentration in the atmosphere for a long enough period to allow the burning material to cool below the ignition point. This time will vary with the extent of the fire and the type of material involved. Deep-seated embers are insulated by over-laying char so that the heat is given off slowly. However, in an enclosed hazard, the amount of carbon dioxide required to maintain the proper concentration for an hour or so is not excessive and elimination of water damage to valuable papers and equipment is of primary importance.

It is not improbable that carbon dioxide can even be used in controlling fires in large petroleum storage tanks. A storage tank with a diameter of 150 feet has a surface area of about 17,650 square feet. The small oil-pool fire previously mentioned which was extinguished with less than 175 pounds of carbon dioxide had an area of 480 square feet. At this same rate, the large storage tank would require less than 6500 pounds of carbon dioxide. This is just a little over three tons of liquid carbon dioxide.

Inerting Explosive Atmospheres

Up to this point, discussion has centered around applications for extinguishing actual fires. Carbon dioxide is also ideally qualified for the job of inerting otherwise explosive atmospheres so as to eliminate any chance of an explosion and the fire that usually follows.

For instance, under certain conditions, the vapor space of large petroleum storage tanks may become filled with an explosive mixture of air and combustible vapors. The percent of combustible gases in the vapor space is a function of the vapor pressure of the petroleum product being stored and the temperature of the liquid. In the case of toluene, the combustible range is from 1.27 to 7 percent toluene vapor in air. The lower concentration is reached at 40° F. and the higher at 99° F. Therefore, at temperatures below 40° F., the vabor-air mixture is too lean to burn and above 99° F. it is too rich to burn. However, in the intervening temperature range, the slightest spark will set off a serious explosion. This hazard can be eliminated by the addition of approximately 30 percent of carbon dioxide to the gases in the vapor space.

Many petroleum products normally have vapor pressures that are high enough to create vapor-space mixtures that are too rich to burn. Some of these may become hazardous during cold weather. An additional hazard may be introduced when removing liquid and so drawing air in through the vent. This cannot happen with butane and similar hydrocarbons which are stored under pressure, but a serious hazard is encountered when placing a storage tank in operation or taking it out of service for repairs. Carbon dioxide is useful for purging jobs of this kind where air must be displaced with a combusible gas or a combustible gas must be displaced with air. There is no cure for explosions. The emphasis must be placed on prevention.

The various applications mentioned are, of course, the obvious ones. When the commercial application in this field develops further, there is no doubt that carbon dioxide will find a place in many detailed operations. In most cases, the question has been one of availability and economy. The growing stature of the carbon dioxide industry has gone a long way toward overcoming these former obstacles. The universal advantages of carbon dioxide for fire prevention and extinguishment can now be employed to a much greater degree. Carbon dioxide can, in fact, become the prime extinguishing agent for petroleum fires, while water and foam are used as valuable adjuncts.

Application of Unit Operations to

Fractionation and Other Vaporization Processes

PART 10

Fractionator Design

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School of Chemical Engineering,
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FRACTIONATION is the process of separating mixtures consisting of two or more chemical compounds into their respective components and in the case of crude oils, into narrow-boiling fractions. These fractions may vary in distillation ranges from 100° F. up to 400° F. for motor fuels, down to substantially pure components having ranges of 2° F. or less. The separation of these various constituents from each other may be accomplished in several ways, such as crystallization, extraction, mechanical separation such as gravitation or centrifugalization, selective absorption and adsorption as well as by stage separation through a process consisting of consecutive steps of vaporization and condensation. For example, wax may be recovered from lubricating oil distillates by fractional crystallization through successive steps of chilling, pressing, and sweating. Extraction may be used effectively by reason of the preferential solubility of an unsaturated hydrocarbon in a certain solvent over that of a saturated organic compound having almost the same volatility. Amorphous wax in heavy petroleum distillates may be recovered by chilling, followed by centrifuging at high speeds. Gases may be separated in a measure by selective adsorption on activated charcoal. Although apparatus used in the above mentioned examples might be considered fractionation equipment in a broad sense, the word "fractionator" usually is thought of in connection with the separation of mixtures through vaporization and condensation steps by reason of the different vapor pressures or volatilities possessed by the components present in the mixture.

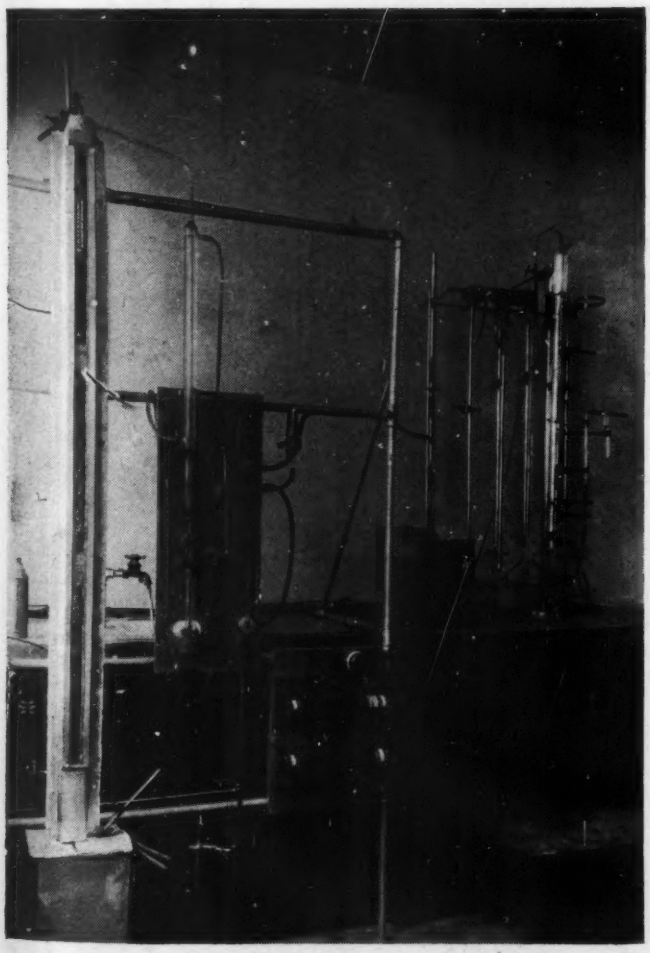

FIGURE 1

True-boiling-point columns. Left foreground, high-temperature column for motor fuels, crude oils and heavier fractions. Right, Podbielniak low-temperature column.

Laboratory Fractionation

Both batch and continuous methods are used in the fractionation of hydrocarbon mixtures. The batch process is employed as a rule in the laboratory, or for the manufacture of relatively small quantities of commercial products.

Laboratory columns are divided into two general types (Figure 1): High temperature columns; (Figure 2) for the fractionation of crude oil and its various fractions, and low-temperature columns (Figure 3) for natural gas and natural gasoline.

In the operation of the high-temperature columns, the fractions boiling up to 400° to 450° F. are taken off as a rule at atmospheric pressure. The apparatus is then allowed to cool so that the heavier fractions may be distilled at reduced pressures, temperature corrections being made on vapor-pressure charts in order to estimate the boiling points at atmospheric pressure. Were vacuum not employed in such fractionations, the residuum at the base of the apparatus would crack, and thereby change the composition of the original crude oil. A sudden decrease in the overhead-vapor temperature is often a good indication that cracking is taking place in the base of the col-

umn as the result of the formation of low-boiling "cracked" products.

The ordinary crude oil has such a large number of hydrocarbons contained in it, that fractionation in the usual laboratory column (5 to 6 feet in height) does not detect the presence of individual components, due to their respective boiling points being so close together. ASTM and fractional distillations on the same crude oil give curves which are distinctly different, as shown in Figure 4. The ASTM test

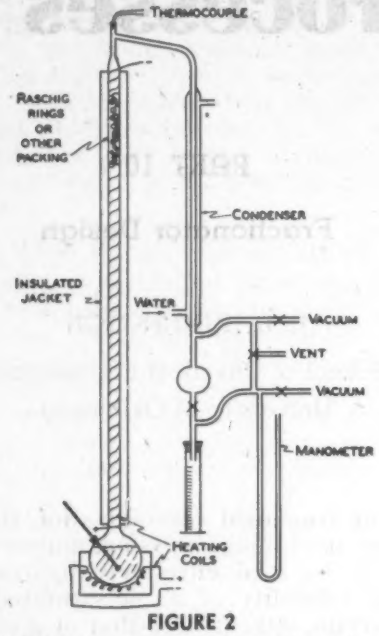

FIGURE 2

High-temperature true-boiling-point column

(somewhat similar to the Engler) is carried out in a flask with a short unpacked vapor column in which very little, if any, fractionation takes place. As a result of this lack of separation, the ASTM test does not come so near to indicating the true-initial-boiling point since some heavier components come overhead with the lower-boiling ones. Likewise, a lower end-point or maximum-boiling temperature is obtained with the ASTM.

The efficiency of any laboratory packed column is expressed in height equivalent to a theoretical plate, i.e. the greater the efficiency the less the column height required to bring about a definite separation. The secret of a good packing material is that of securing intimate contact, between the rising vapor stream and the descending liquid films. Many investigators[1,2,3,4,6] have made exhaustive studies of various types of packing, by fractionating known mixtures of hydrocarbons.

Low-Temperature Fractionation in the Laboratory

The analysis of natural gas, natural gasoline, highly gas-saturated crude oil and distillates, generally is made at low pressures and temperatures in apparatus similar to that shown in Figures 1 and 3. Constituents such as water vapor, carbon dioxide, hydrogen, oxygen, hydrogen sulphide should be determined by other means such as absorption or selective combustion.

The hydrocarbon mixture is liquefied at first in the base of the column with liquid nitrogen. The spiral packing in the column is then allowed to become wet by removing refrigeration at the base and by chilling the top of the apparatus. Methane is taken off overhead as a vapor at the boiling point of that hydrocarbon, the receiving flask having first been evacuated. The increase in pressure in this flask is used as a means of measuring the volume of gas entering it. As soon as most of the methane has been fractionated out of the sample, the temperature has a tendency to rise, due to the admixture of ethane at the top of the column. The rate of product removal is then slowed down in order to secure shaper separation between the pure hydrocarbons.

Pentane and heavier fractions are taken off as vapor at sub-atmospheric pressures, otherwise condensation would occur in the vapor-delivery line and the manometers. Toward the latter part of the fractionation, heat is applied to the internal electrical resistance in the distilling bulb at the base of the column, and refrigeration is discontinued at the top. A typical low-temperature analysis is shown in Figure 5 with a graph of overhead vapor temperature versus pressure build-up in the receiving flask.

In the complete analysis of a gas-saturated crude oil, the lighter fractions such as hexane and lower are fractionated out at low temperatures after which the topped crude oil is transferred to a high-temperature column for more complete fractionation of the heavier ends.

The pressure of nitrogen cannot be detected readily since it will come overhead as a gas along with the methane. The methane and nitrogen mixture, therefore, should be isolated in a weighing flask. Should nitrogen be present, its greater density would cause the sample to be heavier than that of

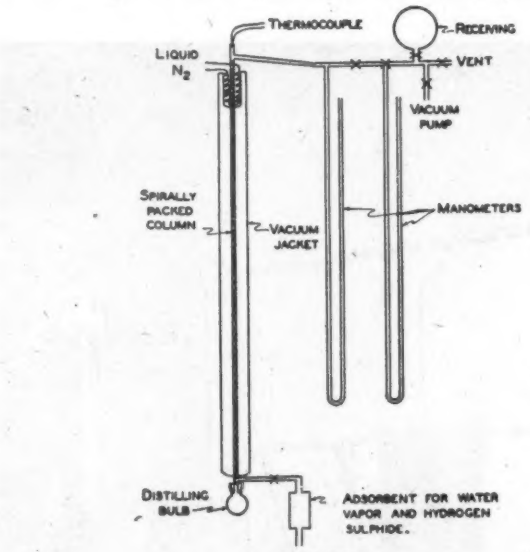

FIGURE 3

Low-temperature true-boiling-point column

methane. If the specific gravity of the nitrogen-methane mixture is 0.60, the volume percentage of nitrogen could be calculated as follows:

$$(x).965+(1-x).552=0.60$$

Where

x = volume fraction of nitrogen present
$1-x$ = volume fraction of methane present
0.965 = sp. gr. vs. air for nitrogen
0.552 = sp. gr. vs. air for methane
x = 0.116 (volume fraction of nitrogen present in the nitrogen-methane fraction).

Fractionation of Two Component Mixtures

In several papers[5] of this series, certain physical relationships between the variables, temperature, pressure, and composition, have been shown for binary mixtures which provide the groundwork for an understanding of fractionation. The most useful graph

for the theoretical calculation of the number of equilibrium trays required for a definite separation of a binary mixture into relatively pure constituents, is the vapor-liquid McCabe-Thiele equilibrium curve. This curve shows the relationship between the composition of the more volatile constituent in the vapor and the liquid ranging from 0 to 100 percent, all at one pressure. The reason for taking pressure as constant is based upon the fact that the differential in pressure throughout the height of a fractionating column is small in comparison with the temperature range from the top to the base of the tower. Fractionation could be effected through the operation of a column having a constant temperature from top to bottom were it mechanically feasible to provide appreciable pressure differentials between the successive bubble trays. Stage separation of oil-gas mixtures by several equilibrium flash vaporizations at different pressures might be considered an approach toward this type of fractionation, however, it does not provide the customary counter-current reflux flow as used in fractionators.

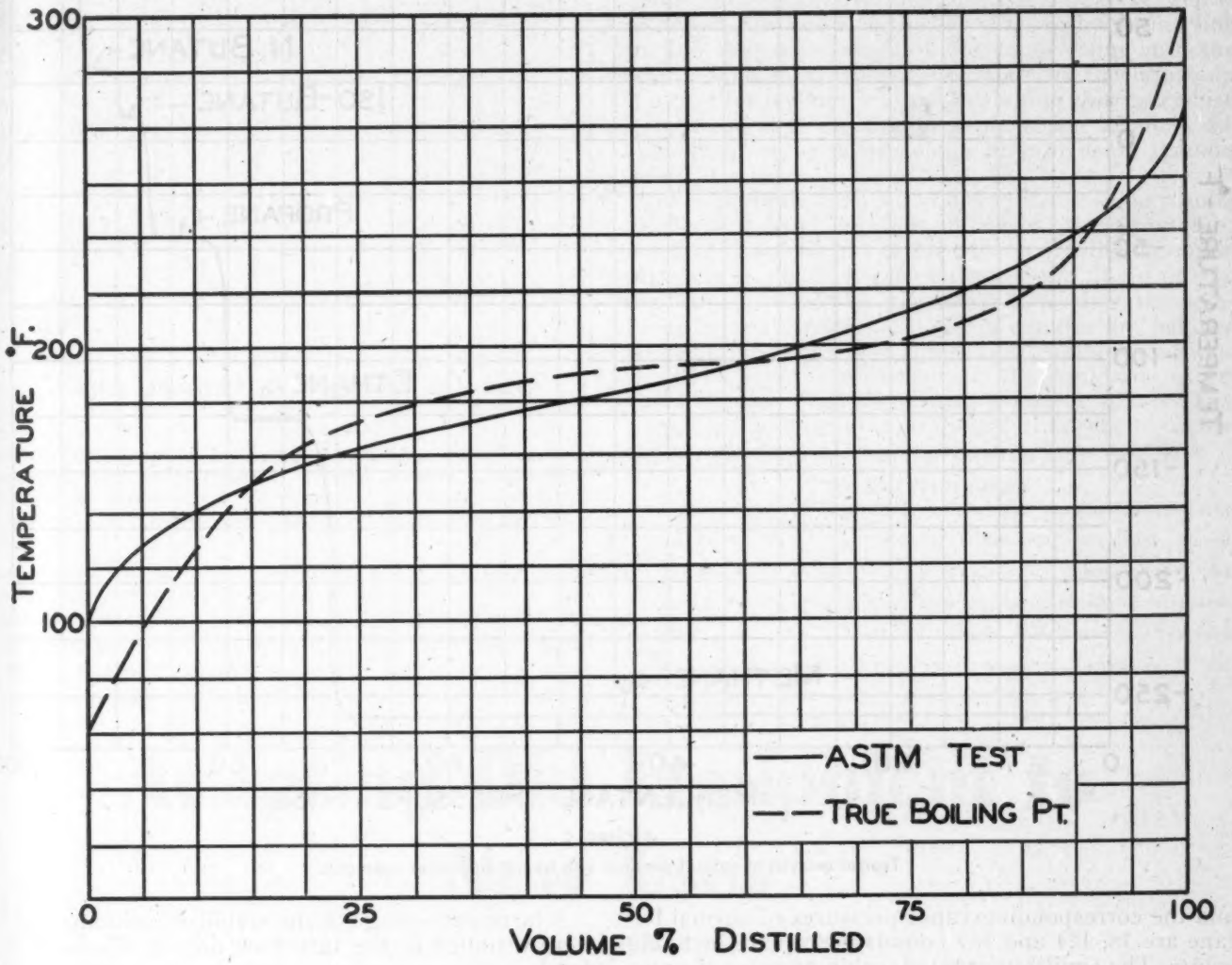

FIGURE 4
Typical distillation curves.

N Butane—Propane Mixtures

If Raoult's law is assumed to be sufficiently accurate for the estimation of the liquid-vapor equilibrium curve, the following procedure for obtaining the corresponding mol fractions of the more volatile constituent in the vapor and in the liquid, may be used. If the overhead vapor is to be totally condensed in coils in contact with atmospheric cooling water, it is probable that the water will run as high as 90° F. in temperature when the wet bulb is 80° F. The condensate or reflux will be about 20° F. higher than the cooling water for conventional design, or in this case 110° F. The vapor pressure of propane at 110° F. is 215 pounds per square inch, absolute, or approximately 200 pounds gauge pressure at sea level. The other extreme of the binary mixture range would be pure normal butane which has a vapor pressure of 63 pounds per square inch, absolute, at 110° F., but it requires a temperature of 207° F. to cause normal butane to exert a vapor pressure of 215 pounds per square inch, absolute. If it were possible to separate normal butane and propane completely in a column operating at 215 pounds per square inch, absolute, the temperature would range from 110° F. at the top in the condenser to 207° F. at the base. Intermediate values for vapor and liquid compositions between 100 percent normal butane and 100 percent propane can be calculated without the trial-and-error method by selecting several temperatures between 110° F. and 207° F., such as 125°, 160°, and 195° F.

The vapor pressures of propane at the above temperatures are 225, 375, and 475 pounds respectively,

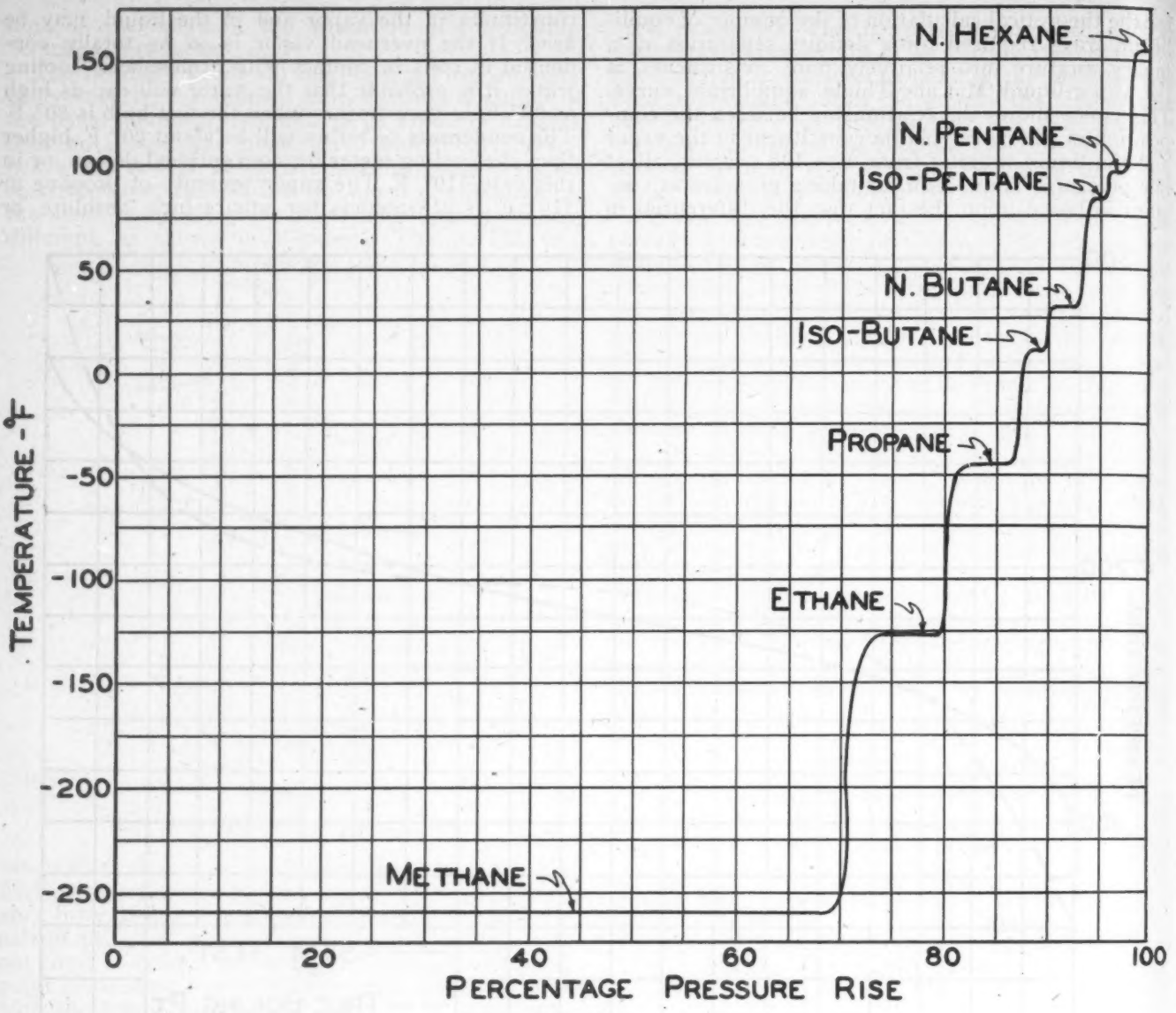

FIGURE 5

Typical analysis of natural gasoline with true-boiling-point apparatus.

and the corresponding vapor pressures of normal butane are 78, 124 and 187 pounds per square inch, absolute. The equilibrium relationship between the partial pressure of each component in the vapor and in the liquid may be expressed by Raoult's law:

Example 1 (125° F.)

[(Total Pressure) (mol frac in vapor)] (Partial Pressure in liquid phase)

or or

Partial Pressure in vapor phase = vapor pressure X mol fraction in liquid

Propane (C_3H_8)	(1)	215	(y_3)	= 255	(x_3)
N Butane (C_4H_{10})	(2)	215	(y_4)	= 78	(x_4)
	(3)	215	(1—y_3)	= 78	(1—x_3)
	(4)	Adding equations (1) and (3) 215 = 78+177x_3			
	(5)	$x_3 = 137/177 = .774$		$x_4 = 1-.774 = .226$	
	(6)	From equation (1) $y_3 = 225/215 (.774 = .916$		$y_4 = .084$	

In a similar manner it is found that the values for 160° F. and 195° F. are:

	160°F.		195°F.	
	(x)	(y)	(x)	(y)
Propane	.354	.618	.097	.214
N Butane	.646	.382	.903	.786
	1.000	1.000	1.000	1.000

A large percentage of the stabilizer columns which were installed in the 1920-1930 decade, operated under lower pressures and temperatures, through the use of propane as a refrigerant. Fewer theoretical trays were required because of the higher relative volatility of the hydrocarbons under lower pressures. In Figure 6 it is easy to see how much greater the relative volatility (Curve 2) is at atmospheric pressure than it is at a pressure of 215 pounds per square inch, absolute (Curve 1). These low-pressure towers were rapidly replaced by the high-pressure columns in view of the cheaper refrigeration cost through the use of atmospheric cooling water. Furthermore, the permissible mass velocity of the vapor is greater in the higher-pressure towers.

Minimum Theoretical Tray Requirement

If a 50-50 molal mixture of propane and normal butane is to be fractionated in such a manner that the overhead product will be 97 mol percent propane, and the bottoms 3 percent propane, the number of theoretical trays can be calculated algebraically (Sorel method)[7] or graphically by the McCabe-Thiele method.[6] For a minimum number of trays, infinite reflux would be required, i. e., substantially no prod-

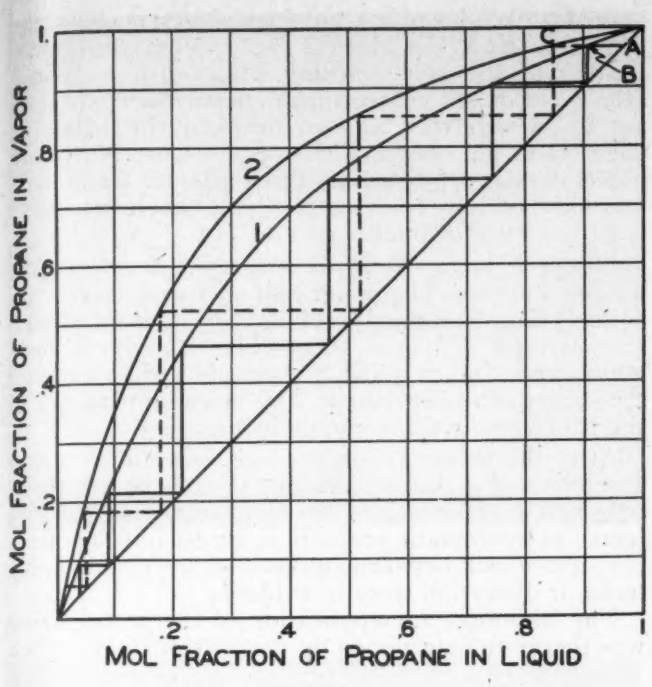

FIGURE 6

McCabe-Thiele graphical method for determination of the number of theoretical plates for fractionation of binary mixtures. Comparison of high and low pressures. Curve 1 equals 215 pounds per square inch, absolute. Curve 2 equals 14.7 pounds per square inch, absolute.

uct would be removed overhead or at the base. The operating or material balance line both above and below the feed plate would be represented by the 45° slope since the vapor rising into each tray would have the same composition as the liquid on the tray. The number of trays found by the graphical method have been drawn in for both the high and low-pressure towers. Point (A) represents the total overhead condensate which has the same composition as the vapor rising from the top tray in the fractionator. The liquid on the top tray has a composition of 91 percent propane corresponding to (B) on the equilibrium Curve 1 and to (c) or 85 percent propane for Curve 2, both obtained by reading valves directly below these points on the abscissa. The next step is to drop a line down to the 45° slope or operating line to find the composition of the vapor rising into the tray, which is, of course, the same as the liquid on the tray for infinite reflux. Continuing this procedure it is found that the low-pressure tower requires 4.5 theoretical trays whereas the high-pressure column needs 6.0 trays.

The algebraic method would give the same results as the graphical solution, however, the amount of work required would be far greater for the algebraic attack. For the first calculation of the liquid on the top tray, it would be necessary to assume temperatures by trial and error until an equilibrium balance was obtained such that the sum of the mol fractions would be equal to unity both in the liquid and in the vapor phases. This calculation would be followed by a material balance around the tray in order to obtain the composition of the vapor rising into the plate.

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Adapting Old Equipment to New Uses

DONALD E. EVANS and WALTER B. MEYER
John Nooter Boiler Works Company
St. Louis, Missouri

THE problem of finding a suitable metal for resisting the attack of various chemical reagents, heretofore never encountered in the petro-chemical field, has been occasioned by the advent of new processes in the manufacture of petroleum products.

As the demand for 100-octane aviation gasoline became crucial, new processes were developed. These new processes called for the introduction of new materials and alloys that would meet the new corrosion problems involved. Nickel was found to be one of the most satisfactory metals for resistance to strong alkalies.

In view of wartime restrictions, scarcity of material and skilled labor, it became apparent that the adaptation of present equipment to new processes was not only practical, but imperative. The problem was one of application of nickel lining to existing equipment. The use of nickel was dictated by the fact that it was the only practical material for use in resistance to the various corrosive mediae involved.

Heretofore nickel linings had been applied to the interiors of existing steel vessels by plug welding nickel sheets with 130X monel metal rod. This procedure had been standard practice in the past. However, monel metal proved to be the weakest link in the chain. In certain refining processes, it is attacked by the various reagents, leaving porosity in the welds. This precluded its use as a filler rod for bonding the nickel linings.

We present herewith a specific example involving the conversion of an existing steel pressure vessel to meet new and more severe operating conditions. This indicates a method of expediting the manufacture of a material vitally needed for the defense of our way of living. This case deals with the conversion of a 4 x 16-foot steel vessel to the production of 100-octane gasoline. The shell was 15/16-inch thick; the heads were 2 to 1 ellipsoidal; the operating conditions were for 450 pounds per square inch at 525° F.

In adapting this vessel to new service conditions,

it was necessary to remove various nozzles and couplings, and to blank off the resultant openings. In closing these openings, both shell and patch were beveled and butt welded inside and out with mild steel rod.

After these preliminary repairs were made, the entire vessel was X-rayed and stress relieved in accordance with the dictates of the API-ASME code.

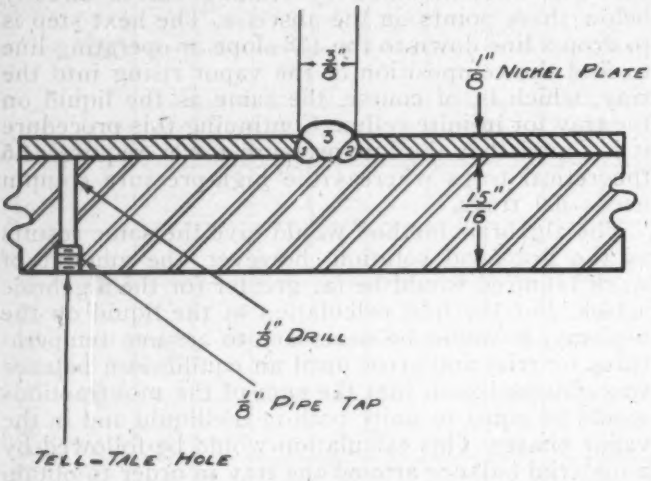

FIGURE 1

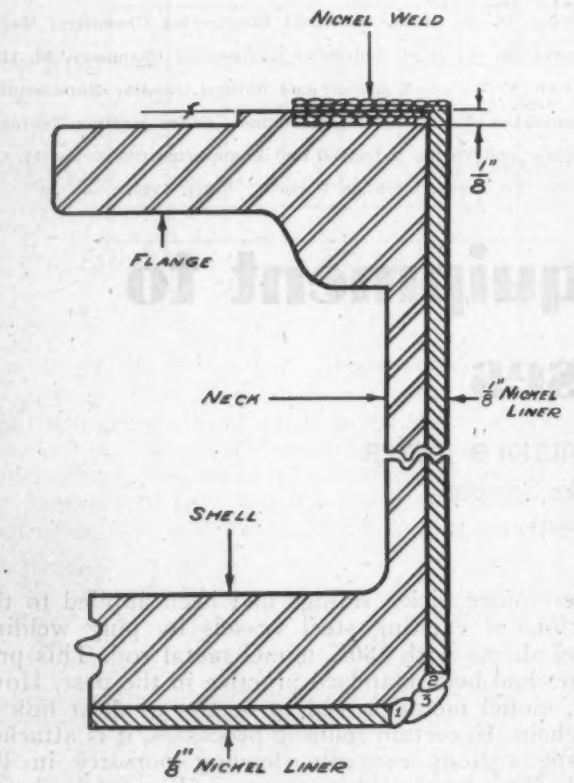

FIGURE 2

Several test plates were prepared before the actual application of the nickel lining was performed. These test plates were designed according to the dictates of good shop practice. Each specimen consisted of a 3/8-inch mild steel backing plate surfaced with 1/8-inch nickel sheet, as shown on Figure 1.

Research indicated 7/8-inch diameter holes on 6-inch centers the most desirable. X-rays proved that this procedure produced a weld free of gas pockets and slag inclusions. The edges of these nickel sheets were welded to the steel backing plate with a 1/8-inch fillet weld of 131 coated nickel electrode. A space of 3/8- to 1/2-inch was allowed between the adjoining edges of nickel sheets. These spaces were filled with nickel welds deposited in three passes. Great care was exercised in removing all slag as each successive weld bead was applied.

Figure 3 is an X-ray photograph of one of the welded samples. The upper half was perforated with 5/8-inch holes for plug welding. The bottom section had 7/8-inch diameter holes. The transverse bead which joins the two nickel sheets is visible through the center of the specimen. The visual appearance of the transverse weld is shown in Figure 4.

After the proper procedure was determined, a test specimen 18 inches square, by 1/8-inch nickel sheet, plug and edge welded to 3/8-inch steel plate, was subjected to hydrostatic pressure in excess of 600 pounds per square inch between steel and nickel cladding. No leaks or distortion were in evidence.

The technique for application of the nickel lining was therefore determined by the previously described

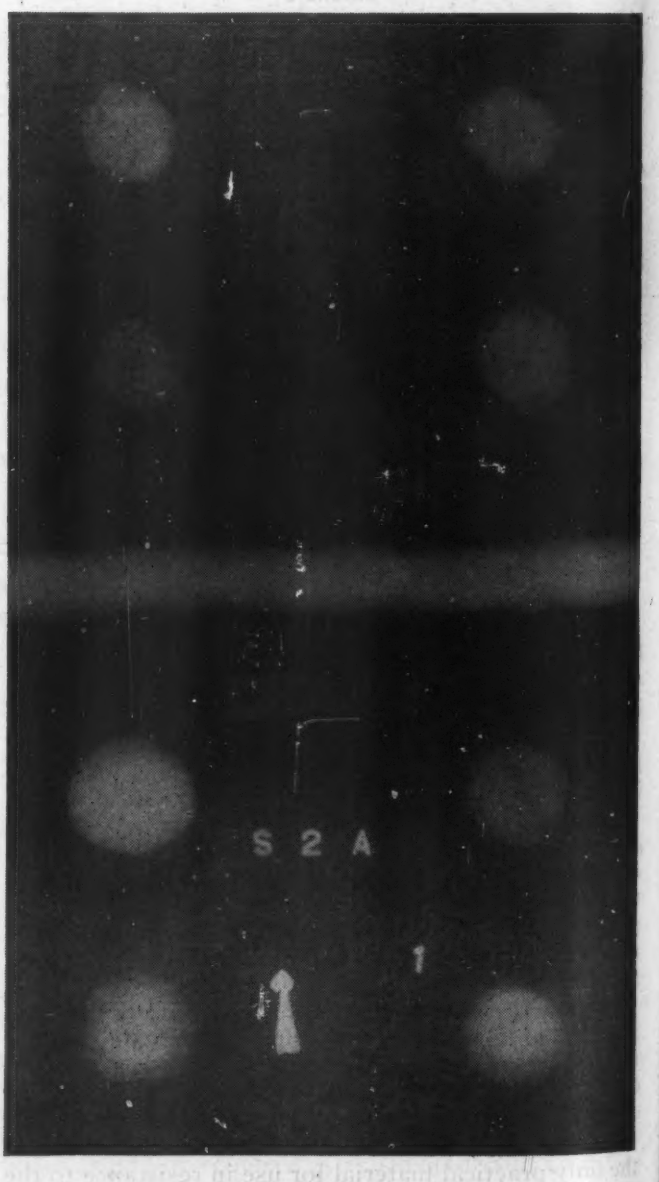

FIGURE 3

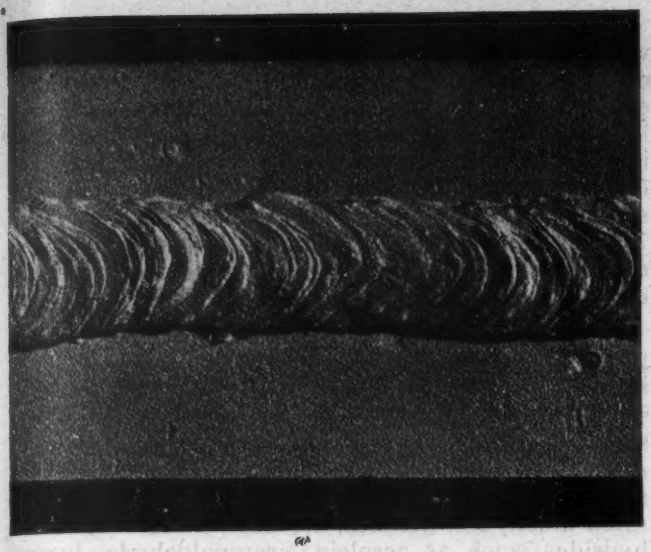

FIGURE 4

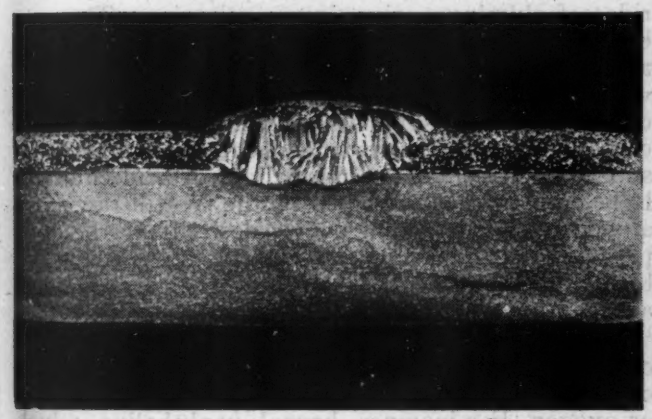

FIGURE 5

samples. The size of the nickel liner plates was limited by the dimensions of the access openings.

The shell liner plates, which were 12 inches wide, were punched down the center with 7/8-inch diameter on 6-inch centers. These strips were formed to the radius of the shell. They were then plug welded to the base, and edge welded to each other and the base, as previously described. The head segments were of the "orange peel" type. These were formed and attached in a similar manner.

The lining of the nozzle necks and the facing of the flanges again required a new technique arising from the varying sizes. In all cases the flange faces were recessed by machining 1/8-inch deep, and to a diameter equal to the outside diameter of the raised face of the companion flange. The neck linings consisted of rolled sheets in the larger nozzles and manway. The smaller nozzle necks were lined with tubing. The nickel liner for the necks extended approximately 1/16-inch beyond the final finished height of the raised face. The liner neck was welded to the flange, and the recessed area was overlaid with 131 nickel rod to a height sufficient for the flange to be machined to standard dimensions. The nozzle liner was attached to the nickel shell liner in a manner similar to the longitudinal seams, i.e., in three passes. See Figure 2 for details of the lining, facing nozzles, and connecting them to the shell liner.

All welding was done with 5/32-inch diameter shielded nickel electrodes. Each sheet of nickel was welded to the shell as an individual unit. The seams along the edges of the nickel sheets were welded in three passes, in accordance with the procedure dedeveloped on the test plates. Figure 5 is a cross section of a typical longitudinal seam. Figure 4 shows the visual appearance of the same weld. In welding the plugs, the arc was struck simultaneously on nickel and steel backing plate. Figure 6 shows cross section of plug welds. The bead was run around the periphery, and worked toward the center.

After the lining had been installed, the entire assembly was subjected to a pneumatic pressure of 10 pounds per square inch between the lining and the shell. Each section of nickel sheet was a unit in itself, and had to be tested individually. Then the interior of the tank was subjected to a hydrostatic test of 750 pounds per square inch. No leaks were evident in either of the two tests.

This vessel is now operating with "weep" holes left open, and they indicate that all welds are satisfactory.

FIGURE 6

Preparation of Drying Oils from Petroleum

DR. F. CHRISTMAN

Translated from "Fette und Seifen," 49, 524 (1942), by Edwin J. Barth, Petroleum Technologist

IT WAS proposed some years ago to prepare drying oils from petroleum by chlorinating the latter and treating the chloro product under heat with zinc dust, during which hydrochloric acid is removed, forming unsaturated hydrocarbons. Another procedure was to treat kerosine, or a partially refined lignite tar, with phosgene, using aluminum chloride as a catalyst. Yields in both cases were poor.

We have now discovered a method to increase the yield of unsaturated oils by using as a starting material high-molecular-weight hydrocarbons, rich in hydrogen, say at least 13.5 grams of hydrogen (preferably 15 grams) per 100 grams of carbon. This raw stock will furnish material high in unsaturation when treated with metallic halides or the halides of boron, simultaneously with acid halides, especially phosgene. Especially high yields are obtained when the unsaturateds are treated with the above halides in the presence of hydrocarbons which contain one or more double bonds.

Hydrocarbons rich in hydrogen suitable for this purpose are the hard or soft paraffins, ceresin, ozokerite, montan wax, crude vaseline, paraffinic residues or lubricants rich in hydrogen, or other heavy fractions from petroleum or lignite tars which have been solvent-treated to remove hydrogen—poor portions of these oils. The oils made by hydrogenating carbon monoxide, at low or high pressures, are especially suitable which are highly paraffinic or which can be also olefinic in character; oils made by polymerization of cracked gases also are suitable as well as the so-called voltol oils. Oils originating from coal which has been hydrogenated, and regular hydrogenated petroleum oils are likewise suitable.

To obtain the unsaturated high-molecular-weight hydrocarbons the above raw stocks are cracked (dehydrogenated) at over 350° C., preferably in the presence of splitting-catalysts, such as bleaching-clay previously treated with hydrofluoric acid, or colloidal clays, or the metals of the sixth group. Dehydrogenation also could be accomplished by sulphur- or oxygen-containing gases.

A preferred procedure for obtaining the desirable unsaturateds is to treat the above raw stocks with halogen, sulphur, or oxygen, best in the presence of catalysts such as iodine or antimony trichloride, and to split these elements out later in the form of their hydrogen derivatives, such as HCl, H_2S, or H_2O. The splitting is best done between 100°-350° C. in the presence of mild condensation catalysts, such as bleaching clay, boric or oxalic acid, or the complex Ansolvo-acids or their salts; halogen halide is also a condensation agent.

The olefines so obtained also can be further mixed with low-molecular-weight diolefines, such as butadiene, isoprene, chloro-butadiene, diallyl, piperylene, conylene or the triolefines such as allylene, crotonylene or vinylacetylene using as much as 20-60 percent in the mixture. A mixture of olefines and diolefines can be obtained directly by heating the above raw stocks to much higher temperatures—to say, 500°-700°C., or by originally using 15-25 percent halogen on the raw oils, followed again by the dechlorination or splitting off of halide, etc.

This olefinic, diolefine mixture or mixtures of triolefines is next condensed, preferably at between 30°-70° C. It is well to condense in the presence of a solvent such as ethylene chloride or carbon tetrachloride.

One can also add to the mixture to be condensed such unsaturated oxygenated materials as unsaturated aldehydes, ketones, alcohols, acids or acid anhydrides, such as acrolein, crotonaldehyde, furane, geraniol, phoron, crotonic acid, maleic anhydrite, mesityl oxide, etc.

The metallic halides to be employed are the chlorides of aluminum, zinc, iron or titanium. These or boron fluoride are added to the olefinic mixture in amounts of 5-35 percent. Into this mixture, during very active stirring, are led 10-35 percent of the acid chlorides, such as phosgene or thionylchloride, or carbon monoxide or hydrogen chloride under pressure. The percentage of the halides or acid chlorides to be employed is dependent on the type of raw stock and also on the iodine value desired on the final product. It is advisable also to add substances capable of slowing down the activity of the catalyst, such as small amounts of zinc oxide or traces of ammonia.

The condensation also can proceed in the presence of small amounts (1-20 percent on the raw stock) of cyclic oils which also may contain sulphur, nitrogen or oxygen. For instance, benzol, naphthaline, toluol, fluorene, anthracene, pyrene, phenol or the ether such as guaicol may be added, and especially useful are hydrogenated cyclics, such as decahydronaphthalin, or raw oils containing such oils from the hydrogenation of coal.

The procedure superficially outlined above will yield highly unsaturated viscous oils, of molecular weight about 450, and iodine number of 100-160. They are useful as drying oils, as such, or can be added to vegetable drying oils, etc. These oils will dry to hard elastic films when exposed to the air in thin layers. Driers such as the oxides, acetates or borates of lead, manganese or cobalt are excellent catalysts in aiding these films to dry at a fast rate.

Our procedure to produce such products is as follows: 100 parts of the product obtained by the repeated cracking of paraffin wax at 500° C. is first dissolved in 30 parts of ethylene chloride. The mixture is actively stirred during the subsequent addition of 30 parts of anhydrous aluminum chloride and after bringing the mixture to a temperature of 50°-60° C., 15-20 percent by weight of phosgene is slowly led into the flask during the course of several hours.

After the proper quantity of gas has reacted, the stirring is stopped and the aluminum chloride in the mass is now decomposed by the addition of dilute hydrochloric acid. The mixture is allowed to settle and the aqueous layer drawn off and discarded. The solvent is next distilled off from the reaction mass.

A yield of 90 parts of an excellent drying oil is obtained, the oil showing an iodine value of 115.

The Growth Factor in Small Business

EARL P. STEVENSON, President, Arthur D. Little, Inc.

(Before Standard Oil Development Company Silver Anniversary Forum, New York, October 5, 1944)

IN OUR zeal for generalization and oversimplification we speak of small and large corporations and attempt to fit all industrial enterprises into one or the other category. Yet no criterion justifies a sharp line between these two groups, even though we can agree on the proper category for almost any one company. Among the criteria often applied is capitalization,[1] and here the twilight zone might be fixed as between one and five millions of dollars.

Given the question, how can small business serve itself and be served by industrial research and development, gross sales is a more useful figure for defining our subject. Size, however, affords no measure of the extent to which a company should support research, as both opportunity and necessity vary widely with different kinds of enterprise. The 1940 survey of the location and extent of industrial research activity in the United States shows clearly that although a substantial number of small and medium size corporations engage in research, their total effort is relatively small. The bulk of industrial research is supported by comparatively few large corporations.[2]

It is characteristic of smaller companies that their research activities are not set apart in a functional unit. The individual in charge of a company's research activities will have other administrative responsibilities; those engaged directly in the work itself may have other duties. The research activities of small companies tend naturally to be individualistic. Research may center in a close group of technically trained operating executives or in one inventive type of individual. These widely varying circumstances are a major factor in determining the relations of the professional research organization to small industrial enterprises.

There is some misunderstanding as to the size of company which employs the services of the research consultant. While it is dangerous to generalize from one example, I venture the opinion that the situation of other research consultants is not unlike that of Arthur D. Little, Inc. Our clients are found largely among the medium size ($1-$10,000,000 capitalization) and the large corporations. By number, possibly 20 percent of our clients are small companies, and from these we derive less than 5 percent of our current income from professional services.

As recently pointed out by Mr. Fairfield E. Raymond,[3] "The small enterprise has the option of carrying on whatever sort of research it can afford, of developing its own technique, of training its own technicians and experts, of acquiring new knowledge by hiring trained engineers or by participating in professional-society activities, by paying for the services of consultants or scientists, by financing specific research projects through technical institutions, or by buying outright new technical developments or inventions from individuals or other companies." A company must make a judicious choice between these several options. With changing conditions a company so situated would be expected to shift its policy from time to time as necessity dictates.

My own experience confirms Raymond's finding as to the intermittent and irregular use of the preceding resources. The reason is to be found in the limited means of the small company for the support of any sustained long-term research effort. While the percentage of gross sales spent by small concerns varies, quite widely, according to recent surveys,[4] 2.5 percent of gross sales appears to be an average figure. A conservative company adhering to the average and with a million dollar sales may be expected to have a research budget of $25,000 a year. In order that this budget may be used effectively the company must allocate a major part to immediate organizational expense, for, as pointed out in an earlier paper,[5] the services of a research consultant and related agencies are seriously handicapped if the client does not have on his own staff at least one individual competent to participate in the work and to see that the findings are intelligently and usefully applied.

It is becoming increasingly necessary for the small company to support a technical staff, and it is from these expenditures that it may expect to receive the highest return. Such a group can participate with benefit in the activities of the scientific and technical societies related to the company's industry, in the use of technical data published by the technical and scientific societies and government laboratories, through contacts with educational institutions, and through the assistance of large industrial research organizations that are back of the materials used by the company. As a matter of fact such representatives of small industry are constantly calling upon the research consultant and thus availing themselves of the somewhat institutional position of such organizations. In other words, there is greater participation in the activities of small companies than would be indicated by the figures which I have cited in the case of Arthur D. Little, Inc.

Mention should be made at this point of the services rendered by individual consultants. As a group they may be more adaptable to the intermittent and informal relations required by small companies than are the larger engineering and research institutions. A few years ago the combined Engineering Societies of New England published a directory of "the New England research agencies, consulting services and colleges and universities available to New England's industrial, commercial and other interests for the solving of their problems by the practical application of the research method."[6] Over 500 institutions and individuals are listed. This extensive list is indicative of the great reservoir of technical advisory and co-

operative service available throughout the industrial section of the country, but all too little used by small business.

How to make effective use of this reservoir has been accepted in New England as a challenge. In the fall of 1941 a plan was formulated to assist small industries in their use of research methods. The New England Council with its large membership among all sizes and kinds of businesses was the leader in this project. The situation of New England was surveyed under a committee headed by Dr. Karl T. Compton, president of Massachusetts Institute of Technology.[7] From this developed the New England Industrial Research Foundation, with its major purpose the promotion and utilization of research methods by New England industry, both large and small, but with the needs and problems of the latter a particular objective.

The outstanding conclusions which I have drawn from participation in the administration of this foundation from its inception are (1) that there is a widespread and intelligent interest in research by business executives in small companies, (2) that more funds are available than are being spent, (3) that opportunities for research and development are recognized, (4) that the missing element is in technical and scientific manpower. The program of the foundation can only be implemented by making men available to meet the needs of the progressive small business. In the absence of such help the foundation has largely curtailed its activities for the duration.

The office of the New England Industrial Research Foundation has received inquiries from other industrial areas, and I have no doubt that in the postwar period a number of organized centers facilitating the use of available research aid will be established primarily for the benefit of the small manufacturer. Several states already have annual industrial conferences devoted to the application of research.

If I were asked to suggest specific steps that would aid small industry in the use of research in the immediate future, I would first discuss the matter of employment of men who speak the research man's language—men trained in our great technical educational institutions. It is not sufficient for the business executive to be sympathetic toward research; he must also have an understanding of its techniques and the ability to select the right kind of men.

It is evident from the record that large companies hire most of the technical men. Experience in this respect at the Massachusetts Institute of Technology is believed typical of the better technical schools, and it shows that the large companies have studied the competition in their technical graduate supply market, and that they compete seriously and effectively for a continuing flow of young technical graduates into their organizations. Not so the small companies. Obviously, they have not recognized or realized the need, or have not studied the competition they must meet, for relatively they are not adequately represented in the technical graduate markets each year. It is not that they cannot meet the competition, for the small company appeals to many men merely because it is small, and the small company is much more flexible in the special salary or other conditions it can establish. The relatively few small companies that make a special effort to obtain technical graduates on a competitive basis have found no insurmountable difficulties.

It must be recognized, however, that the large industrial research organization has much to offer the young graduate; pleasant associations that continue earlier friendships, the opportunity to work in fields of specialized scientific interest, the glamour of belonging to a nationally known organization, the promise of early advancement with financial and social security. Also in certain educational fields, notably chemistry and chemical engineering, the leading graduate schools have a definite vocational relationship toward the established manpower requirements of the large industrial research organizations.

An analysis of the list of large companies that maintain the bulk of our research and hire the bulk of our technical men is most illuminating. A major portion of them are found to have started with technical development, to have been built on research and engineering. The names of the great companies with their great laboratories in the electrical, the petroleum, the chemical and process industries immediately suggest themselves. They do not hire technical men because they are large—they are large because they hired technical men when they were small and have kept on hiring technical men. By contrast the railroads, the coal industry, and other industries are large, but they are not relatively good markets for our technical graduates nor have they yet been relatively large supporters of research. The outstanding industries supporting research and hiring our technical graduates year after year are chemicals, petroleum, and the electrical group. The chemical and electrical industries grew from research and the use of technical men. The most spectacular increase in the employment of research personnel in industry in the period between 1927 and 1938, charted by Cooper, is in the petroleum industry. In that period the petroleum industry joined the ranks of those who knew how to use research wisely and generously—and as a result, the industry prospered greatly and the public profited enormously.

Many small companies, if they are to compete and assuredly if they are to grow, must learn first to compete for technical personnel. If competent technical personnel is intelligently absorbed and utilized, effective research will follow almost automatically. There are ample facilities available for advice, consultation, and direct and continuing assistance. Organized bodies, like that sponsored by the New England Council, exist or are being created to facilitate the use of such assistance. Most small companies are probably aware of the significance of research, but many of them are still unaware of the methods by which research can be utilized within their budgets and their organizational structure. The need now is not for more sources of assistance or free service—research bread lines—the need is rather for education of small company management in the advisability of employing technical personnel and in methods of utilizing research assistance now available. These needs, unfortunately, are still great.

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[1] Research—A National Resource. II. Industrial Research. December, 1940. National Resources Planning Board. Section II, 8.

[2] Ibid., Section IV.

[3] Ibid., Section II, page 79.

[4] Ibid., Section II, 8, page 124.

[5] "Management and Research Consultants" by Raymond Stevens and Earl P. Stevenson, Chemical and Engineering News, American Chemical Society, 21, 1869, November 25, 1943.

[6] Directory of New England Research and Engineering Societies, published by Engineering Societies of New England, Inc., in cooperation with the New England Council, May, 1939.

[7] "Industrial Development in New England," an address prepared for delivery before the 75th Anniversary of the University of New Hampshire in the joint meeting of the New England Council and the American Association for the Advancement of Science at Durham, New Hampshire, on June 24, 1941.

The Future of Industrial Research As Seen by a Chemist

THOMAS MIDGLEY, JR., President, American Chemical Society

SOME twenty-five or thirty thousand years ago a new species of animal appeared on this earth. There is nothing remarkable about new species appearing from time to time. The history of the ages is filled with such events; but this particular species differed in one characteristic from all that had preceded it. Instead of adapting itself to the various environments thrust upon it by an unfriendly and ever changing world it had an instinct to adapt its environment to suit itself. Indeed this was the most remarkable characteristic it possessed. It began by exterminating all of its potential competitors within the genus homo, leaving only itself as the representative of that group. Recently it has given itself the species designation of sapiens. Homo sapiens, or in other words, ourselves, began the readjustment of its environment by doing the obvious. It cleared land for agriculture, built houses for protection against the weather and various enemies, including itself and, to a limited extent, destroyed those animals antagonistic to it as best it could. It made into vassal creatures dogs, cattle, chickens and pigs, and changed the nature of many wild plants to make easier its labor of providing itself with food. Yet there remained many parts of its environment over which it could exert no control, for example, lightning, hurricanes, earthquakes and floods. This lack of control puzzled it. Instinct urged it on, and somewhere in its subconscious mental processes mankind felt that a better understanding of that universe, which it knew to be its own, might aid it in its eternal fight to control that universe. At first imagination was given full sway. Superior creatures to itself were conceived of which it assumed had control of many things. Sacrificial offerings and prayers were invented to obtain the friendship of these superiors; but gradually, through the past two thousand years, such childish superstition has been replaced by what we call the scientific process.

What is this scientific process? Indeed, all too often the term is used to glamourize simple common sense, and then again it is used by charlatans to give respectability to what otherwise obviously would be in conflict with common sense. A better definition is desirable. To my mind the basis of the scientific process is the reproducible experiment. Facts are still, and probably always will be, determined by vote; quite as the College of Cardinals determined the number of feathers in the Archangels' wings just a few centuries ago. To the modern scientifically trained mind this process seems somewhat ridiculous; but was it? The number had to be determined for the benefit of painters, sculptors and architects, and how else could it have been done? Indeed, the same process is in use today when groups of scientists gather to hear discussions of controversial subjects. There are, however, two points of basic difference. Whereas the number of feathers was decided by majority vote; in science we require a practically unanimous vote for establishing a fact. The second point is the type of evidence required by the voter to influence his decision. Revelations, dreams, supernatural authority are now out, and even logic is of secondary importance to the reproducible experiment. Mathematics is the only branch of science which claims exemption from this rule. Two thousand years ago, mathematics passed from the realm of the experimental to the utopia of pure logic. It is interesting to note that prior to that time mathematics had been an experimental science. The Egyptians and Babylonians had determined crude values for pi by experimentation, and several formulas had likewise been developed. The Greeks, however, who were long on logic and short on experimentation, transformed mathematics into an exact science; the only transformation of its kind ever to have taken place. Is it too much to hope that other sciences, such as chemistry and physics, may some day be similarly transformed? One may always hope, even though fulfillment is still far away.

ALTHOUGH this paper was not presented for the purpose of revealing the influence of research on employment, it offers sound reasoning in support of that proposition, as this sentence reveals:

"Unless the public cooperates and raises its living standards as rapidly as industrial research makes it possible, unemployment is the inevitable result."

The paper was delivered at the Silver Anniversary Forum, sponsored by Standard Oil Development Company, New York, October 5, 1944.

This address is the last of the work of Dr. Midgley. He died at his home in Worthington, Ohio, November 2, at the age of 55. Death was said to be due to strangulation by a harness with which he helped himself into and out of bed since he lost the use of his lower limbs from infantile paralysis in 1940.

Discoverer of tetraethyl lead as a knock depressant in gasoline, he also invented or discovered 100 other applications in chemical science, including Freon gas for refrigeration, and a method of extracting bromine from sea water.

DR. THOMAS MIDGLEY, JR.

Progress by Patents

Permit me to recapitulate. We are the only species of living creatures that even conceives of exerting any control over the environment thrust upon it. Admittedly, this control is far from complete. Its extension is greatly to be desired. To accomplish this extension we need to increase our knowledge of the universe in which we live. The only fundamental tool at our command, for extending this knowledge, is the reproducible experiment. This is the accepted scientific method, and when applied to obtain a better understanding of our environment is designated by such terms as fundametal research or pure science research or academic research. Once new facts about our environment (which is synonymous with our universe where and when we contact it) are discovered we can make use of these new facts to alter or control our environment to some extent. The process of applying the facts, determined by fundamental research, to a better control of our environment is called applied research or development work or invention.

For some reason, best known to our

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FULL PRESSURE LUBRICATION—Correct, positive lubrication for all vital bearings and reciprocating parts, with force-feed lubricators for power and compressor cylinders. Different grade lubricants may be used for power and compressor cylinders if desired. Oil lines remain filled when engine is not operating.

DUAL LUBE OIL FILTERING—To further assure bearing "health" and trouble-free operation, lube oil is cleaned and decontaminated by full flow metal edge filter and waste-pack bleeder filter. Both filters are easily cleaned while engine is operating.

SIMPLE, EFFECTIVE FUEL SYSTEM—Ported design of the injection valve simplifies accurate regulation; permits easy adjustment for high or low BTU fuels. Cylinder load-balancing is easily achieved. Advanced injector design assures quiet operation and minimum wear.

OIL-COOLED PISTONS—To reduce piston ring and cylinder wear, a continuous flow of oil under piston crown keeps temperature uniformly low, permits minimum piston-to-cylinder clearance, eliminates "stuck" rings and pistons.

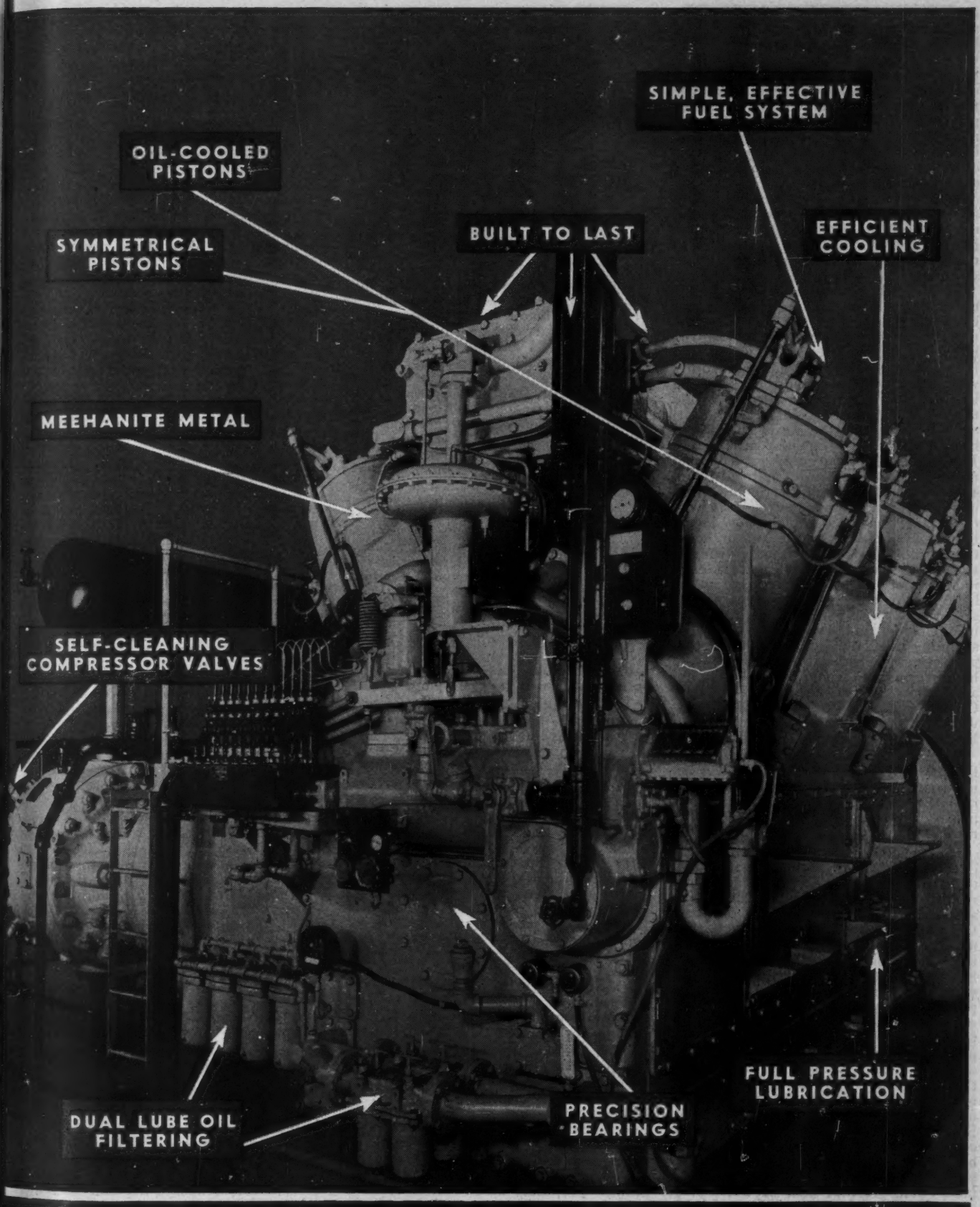
SYMMETRICAL PISTONS—Streamlined scavenging, with directed air flow, permits symmetrical piston crown design. Thus heat is uniformly dissipated to further prolong service-life of rings, cylinders and pistons.

EFFICIENT COOLING—Water jackets are designed for abundant flow to maintain low temperature differential, thus eliminating hot spots and resulting stresses. Clean-out openings are large and conveniently located. Outside water jumpers eliminate troubles encountered in wet-joint-type cylinder heads.

TYPE G·MV ANGLE

Compressors

New York Washington Bradford, Pa. Parkersburg, W. Va. San Francisco, Cal. Seattle, Wash.



by **Cooper-Bessemer**

lawmakers, the discoverers of new facts are denied any special rights to financial benefits that ultimately may result from these discoveries. On the other hand, those who can apply such discoveries to improvements of environment, for their fellow men, are granted the exclusive privilege of exploiting these improvements, for a limited period, providing they make public the nature and details of the improvements in documents called patents.

Whether this arrangement is right, fair or just is beside the point. Under its influence modern industry has come into existence and homo sapiens has made great gains in controlling his environment. This, at least, makes it good.

In the early history of modern industry there is little evidence that it either knew or appreciated the fact that the patent system was responsible for its birth. All it knew or cared about was that it had a steam engine to run machines with, that machines could be operated by men hired at low wages to make things that could be sold at profit. Little did it care that the steam engine had been developed by James Watt because James Watt knew he could get a "patent monopoly" on the results and sell steam engines at a profit. Few of the early units of our "modern industry" gave heed to the fact that they could follow in the footsteps of James Watt and increase their profits by contributing to the inventive and developmental process. Thus it was that, for over a century and a half, the inventor went his lonely way, suffering hardship and sacrifice, often being looked upon as crazy and finally spending the later years of his life in protecting the rights granted to him by his government. If you think this an exaggeration study the life of Charles Goodyear and then ask yourself if it was worth it, just to stand in the Hall of Fame, where he should be, but isn't.

Inevitably industry finally saw the light. Many of you can recall the "drafting room" of 50 years ago, how it grew into the engineering department which in turn gave birth to the research laboratory.

Industrial research has come into existence by this revolution. The field of industrial research is restricted, primarily, to making use of the discoveries of academic research to improve our control over our environment which then may be used for profit making through the patent process. It must be noted, however, that our knowledge of our environmental universe is far from complete and that it often becomes necessary, in the course of prosecuting industrial research, to deviate from the primary process in order to determine additional facts about the universe so that these facts may be applied. There is no legal process for restricting the use of these facts, once determined. Secrecy and secrecy alone can retain control. This is not quite as it should be. There might be some mechanism devised whereby the discoverer of new facts could preempt their use for a brief period; a period at least long enough for him to determine some of their various applications to environmental control. Thus would be established a motive for industrial research to make public, at once, the discoveries it makes concerning the natural laws. I should like to point out, that, despite the profit motives to keep secret the discoveries of fact which are continuously being made by industrial research, the large majority of industrial operators do make these discoveries public within a reasonable time. Such an attitude of conscious service to society should receive more praise and recognition than it does.

Only Catching Up

Instead of trying to aid industrial research to benefit the society which has created it, it seems inherently human for many people to do their utmost to obstruct it. Possibly the suddenness with which industrial research has developed to its present position of eminence has generated unwarranted fears on the part of many people who scarcely understand it; fears that the power it obviously possesses over our future progress may be abused; fears that a monopoly of brains may be in the making, or just plain fears of change. Whatever the fears may be, I am of the opinion that their basic cause is simply the sudden appearance of industrial research in our economy. Had industrial research developed simultaneously with modern industry over the past 150 years instead of merely during the past 25 (to a large extent), these fears would be non-existent. That industrial research should have been developing over the 150-year period seems obvious to us now; its rapidity of growth during the past 25 years has been largely a "catching up" process. Whether or not it has completely caught up with other industrial activities is a question for debate. I am of the opinion that it has not. Assuming that I am right in this opinion there is still a further point for debate. Will it? This is a far more difficult question to answer than the first. It hinges on so many intangible factors, factors which only the future itself will fully develop.

I should like to discuss a few of these factors at random, more for the purpose of disclosing the uncoordinated thinking that is taking place rather than to attempt a solution of any one of them.

For example there is one school of thought, that was rather vociferous some 10 years ago, which believed that all industrial research should be ended for some indefinite period, until, as they expressed it, the humanities had caught up. Since the war developed, these theorists have been rather quiescent; but given a period of unemployment, after hostilities cease, it is a practical certainty they will be heard from again. Frankly, the thought processes involved are beyond my poor comprehension. How unemployment may be reduced by increasing it or how stopping industry will start employment is merely a denial of logic to me.

Then there is the thought that placing all industrial research under governmental direction would result in accelerated progress. I have read the various Kilgore bills and the arguments for and against; but again I must confess that I simply cannot understand the logic involved. Somehow, it seems to me, that the proponents of this and similar proposals assume that research scientists are going to work largely for the pleasure of presenting the results of their labors to society free gratis, without any desire for rewards for themselves. There are such men of course. Thank God there are, for, without them I don't know how we will ever get the next generation of college students educated, but there are none to spare. It is quite true that scientists, as a group, are more willing to work for the sheer joy of satisfying their inquiring minds than are most other people; but it is also true that scientists have wives who want new automobiles and fur coats, quite like physicians' and lawyers' and judges' wives do and scientists have children, just as other folks do, and scientists like to feel that they can raise and educate these children, like other folks do, and to do it they are deserving of an opportunity to obtain a financial reward that is somewhat proportional to the services they render society. I have never been able to figure out where they get it under the Kilgore proposal.

There are also those who would change our patent system. Somehow these people have an aversion to the government granting a monopoly for 17 years to any individual for making public an invention. These people seem to think the government is giving away something to the inventor. Actually, by its very nature, a patentable invention brings into existence with it a natural monopoly, which merely requires secrecy for its preservation. Obviously, the commercialization of many inventions would destroy the secret; but others would not. In either case the inventor could retain his natural monopoly and use it for his own benefits in whatever way he might choose as long as he did not disclose his secret. This is the situation the inventor finds himself in when he goes to the government voluntarily (he doesn't have to go) to accept the bargain the government offers him, which simply is this: "make your invention public and you can retain your monopoly for 17 years." If the government decides to drive a much harder bargain it is permissible to wonder how many inventors will volunteer to surrender their natural monopolies? Certainly those who make an invention which may be exploited and kept secret will scarcely be expected to do so. The results will be disastrous.

The Law Says

Then too there are court decisions that are difficult to understand. The Supreme Court declares that Marconi's patents are invalid for lack of invention after they have expired. In another decision it uses the term "flash of genius," as though the method of making an invention was of more importance than the invention itself. Another court proclaims that an individual can make an invention; but if a group, working together, perform the same act and obtain the same result it is not an invention. It is all very disconcerting. To my way of thinking, which I have tried to develop in the earlier part of this discussion, any increase of control over our environment, or beneficial alteration thereof, is invention. The method by which such results are obtained is of no importance. The attitude of these courts seems to be comparable to a general deciding that if a regiment takes a position from the enemy no advance has been made, whereas, if a single individual does so it is a commendable act and deserving of a medal; in the court cases, a patent.

Some few years ago the enemies of our patent system were in the habit of proclaiming that there were great numbers of "suppressed" patents. A "suppressed" patent was supposed to be a patent of value that was not being "worked" because of some selfish motive on the part of the owner, such as having an obsolete plant that he would be forced to scrap if he put the patent

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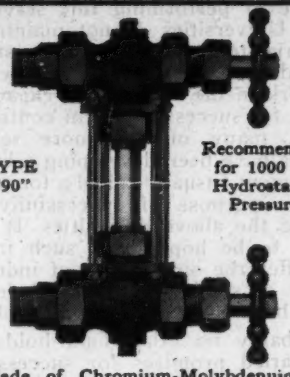

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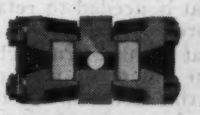

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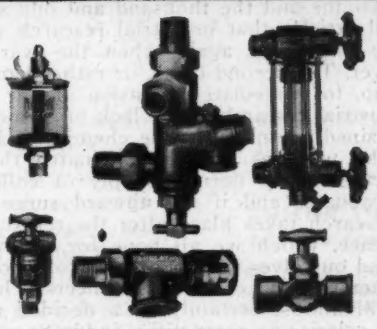

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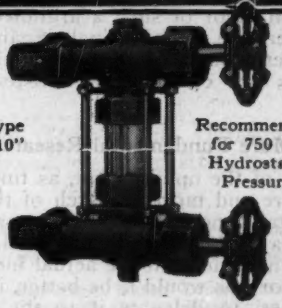

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to work. This story has many variations. Then these propogandists proposed new laws for forced licensig as a corrective measure of this imaginary abuse of our patent system. In the interest of determinnig the facts I issued an invitation in the News Edition of Industrial and Engineering Chemistry to any and all chemists, who might know of such cases, to report them to me anonymously, giving the serial number of the patent. I received five replies. Not a single case was justified. There are no suppressed patents.

I am not here to discuss the future of our patent system and I feel that I have taken more of your time on this subject than could be justified were it not for the fact that the future of industrial research is so intimately bound up with it. I am proud of our patent system, proud of its past record—a record which speaks for itself, and I sincerely believe that this record alone fully justifies its retention.

There will be attacks made on it in the future, as there have been in the past, probably by individuals who have little knowledge of their subject. It would seem that a comprehensive discussion of the exact situation at the time would be all that is needed to retain the merits of our present system.

Assuming that no disastrous changes are made in our patent system, certain trends in industrial research become obvious. Research has not yet come into its own with respect to many of the smaller units of industry. The larger units have been able, because of their position, to pioneer the general movements. This pioneer work was possibly too hazardous for the small units to undertake; but now that the exploratory stage is pretty well over and trained personnel is available for executive positions there is no longer any reason why the smaller units of industry should not make full use of industrial research for their own advancement and welfare. It may be argued that to be efficient a certain minimum sized laboratory is needed and that small organizations cannot afford even this minimum size. There is much in favor of such a argument; but a cooperative, or municipal, organization can overcome this difficulty. Such laboratories are coming into existence already.

More Fundamental Research

I am of the opinion that, as time goes on, more and more research of the fundamental type will be necessary. This raises a serious question. Should such research be done in the actual industrial laboratory or would it be better, in most instances, to delegate it to the educational institutions? Admittedly, some special cases will occur wherein the fundamental knowledge will be needed so quickly that the higher tempo of the industrial laboratory, for obtaining results, will be indicated and other cases will occur where the need for secrecy is so great that it cannot be entrusted elsewhere. However, the majority of cases should be such that they may be safely entrusted to the research staffs of our universities and colleges for study. This attitude should be encouraged whenever possible, for three reasons. First, the university staffs are generally able to bring a much broader vision to bear on these fundamental problems, second, where fundamental problems are being prosecuted in industrial laboratories they have a habit of being set to one side and forgotten when more urgent work develops and third, the work thus given to the educational staffs will be of considerable value in educating future scientists to do more such work.

On the other hand, applied research should not be given to university or college staffs when the industrial unit is capable of performing this service for itself. Universities do not maintain the industrial tempo, nor are their staffs in the habit of, nor should they be asked to, work in the confidential capacity required for successful patent control. Recently, many of our more technical schools have been developing a business department (usually called a foundation) for the purpose of successfully overcoming the above difficulties. It is sincerely to be hoped that such facilities will offer the small units of industry a means of solving many of their problems; both fundamental and applied.

Probably no other field holds more and varied promises for successful industrial research than chemistry: success for the investigator who may satisfy his curiosity about the unknown with a fair share of honor and wealth; success for industry which may increase its payroll, its output and its profits, and success for the public who will reap the benefits of better health, higher standards of living and a safer world in which to live and travel. There are two catches to this charming picture, of which I am aware. First is the recent apathy the public has shown toward raising its standard of living. It is discouraging to develop new things or to open the way to better comfort just to have the public yawn and say, "So what." Unless the public cooperates and raises its living standards as rapidly as industrial research makes it possible, unemployment is the inevitable result. I am not suggesting that the public go on a wasteful spending spree, ending up with little to show for it; but what I do mean is for the public to supply itself with better houses, better lighting, better radios and refrigerators, air conditioning and sound proofing, better automobiles, tires and gasoline and the thousand and one useful articles that industrial research will be improving again when the war is over. The second catch, or rather handicap, to immediate expansion of our industrial research is the lack of properly trained personnel in the chemical fields. The war has already eliminated three years of the normal supply of college graduates and if the upward surge of research takes place after the return of peace, which we all hope for, we will find ourselves very short of professional chemists and chemical engineers. There will almost certainly be a decided rise in salaries as competitive industry again gets under way. This will not be bad for the chemists and chemical engineers who are already in industrial work, but its repercussions on the educational situation may be quite disastrous. The universities are in no position to bid, financially, for the services of the younger men who are needed as instructors, later as assistant and associate professors and still later as full professors and heads of departments. Industry should take heed of this situation before it gets out of hand. By ample fellowships both in size and number it should encourage many young men to remain in educational work in order that its own full needs can be met in the near future.

Always Expanding

A few years ago our fellow scientists in the field of astronomy presented our minds with the intriguing concept of an expanding universe. Although this concept explains the observed fact that lines of the spectrum shift toward the red in proportion to the distance from the earth of the spiral nebulae, it can scarcely be subjected to the rigid examination of the reproducible experiment, and, hence, must be held as speculative until such an examination can be devised. However, in quite a different sense, our environmental universe is definitely expanding. Few discoveries of any importance are made that do not open up still greater fields for future investigation, and, consequently, more knowledge to be used by industrial research.

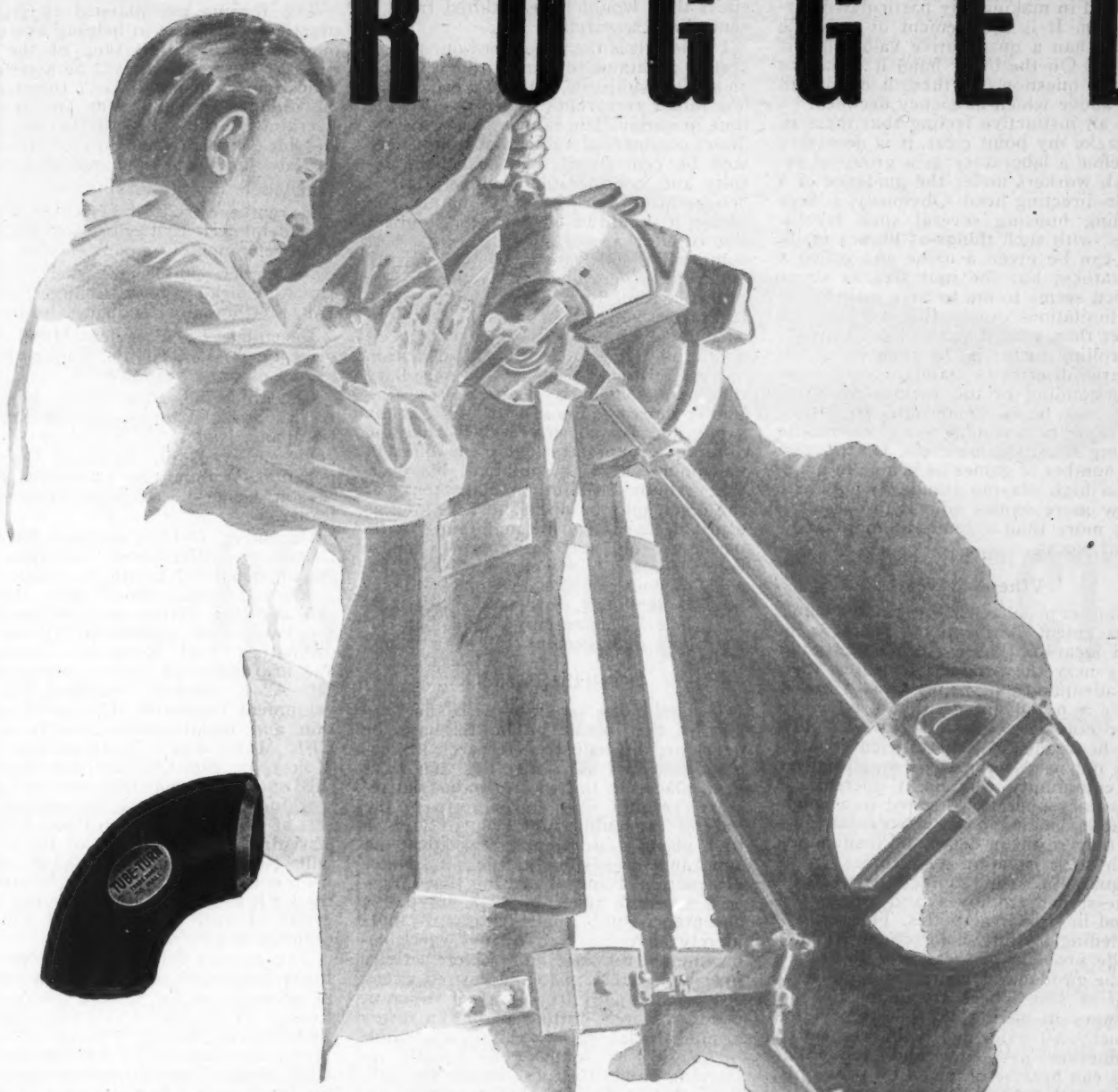
This accelerating expansion of potential fundamental knowledge constitutes an ever-growing stockpile of raw material ready for fabrication by industrial research. Obviously, this indicates a continuation of the expansion that industrial research has experienced during the past 25 years, irrespective of whether the "catching up" process is complete or not. It is difficult to develop any argument to contradict the desirability of expanding our industrial research in view of these realities; but there are other realities which will have a more quantitative effect than mere desirability. During the past 25 years industrial research has expanded ten times. Seventy thousand scientists are now engaged in it. Seventy thousand scientists is a rather large percentage of the total number available. Another sizeable group must remain in educational work, or the whole system will collapse. There is another group that will return with the armed forces which will be available after hostilities cease. However, it is doubtful if their number is much more than will be needed for replacement. Consequently, it is difficult to visualize any sizeable expansion until our supply of scientifically trained personnel can be increased through the normal process of education. This will require at least a few years after the war ends; probably three or four.

Once expansion does set in, management will again be faced by the problems of organization, location and unit size of the new laboratories to be built.

The past 25 years has established certain concepts of research organizaton that we may expect to endure for some time to come. It is scarcely necessary to discuss these accepted principls at this time. The research "team" as a unit in this organization has gained popularity in the recent past. The individuals of any particular team are chosen for their qualifications in their field of specialization, as it is related to the problem to be studied. This is a different approach to organization than the conception of a departmental head, with a variety of assistants. Most unit types have their places. The "team" is better adapted to the solution of problems involving two or more fields of science, while the "head," with assistants, works best on problems substantially confined to a single field. It has been observed that the problems involving multiple fields are becoming more numerous and hence the team conception is gaining in practice.

I have already mentioned that a minimum size of laboratory is indicated for retaining efficiency. It would be dog-

RUGGED



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matic to attempt to define such a minimum, since many variable factors are involved in making any particular determination. It is a statement of principle rather than a quantitative value that is implied. On the other hand it is fair to ask the question "Is there a maximum size, above which efficiency declines?" I have an instinctive feeling that there is. To make my point clear, it is necessary to define a laboratory as a group of research workers under the guidance of a single directing head. Obviously, a large building housing several such laboratories, with such things as library facilities, can be given a name and called a laboratory; but the unit size as above defined seems to me to have rather definite limitations. Again, this is a principle rather than a fixed value. The obviously controlling factor is the capacity of the research director to maintain an efficient understanding of the various problems for which he is responsible. In a way, this capacity is similar to a chess master playing simultaneous chess. Up to a certain number of games he is able to maintain a high playing standard; but, with a few more games added, the result is little more than a semi-automatic moving of pieces.

Where to Work

Another problem that eternally plagues management is location. There is no ideal location. There are advantages in being near the production center, there are advantages in being away from it. There is no advantage, that I am aware of, in complete isolation. No laboratory can be made so self-sufficient that it does not need services or supplies from the community wherein it operates. A laboratory operation located in a neighborhood lacking any such essentialities can only result in delay and inefficiency. With such isolation also comes an inadequacy of social contacts between the professional employes and others engaged in similar activities. The result is deadening to the whole organization.

The problem of location with respect to the production center is familiar to most of you. There are undeniable advantages in having the laboratory personnel well informed with respect to production problems and economies. This can best be obtoined by proximity. On the other hand, the proximity of the research laboratory to production is an ever-present temptation to the production management to draw the laboratory into undertaking or studying the daily "bread-and-butter" problems which the production unit should be capable of solving for itself.

I know of two extremes within the same industry, one going so far that it disperses its laboratories among its various production departments, while the other operates its research laboratories at an overnight trip from the plant. Seemingly, both operations are equally successful. Possibly the solution for maximum results can be obtained by having two laboratories; one at the plant and another a few hundred miles distant. Ultimately, the problems each is best adapted to solve will find their proper atmosphere.

Duplication of effort is another problem that faces most research executives. It is very noticeable following some strinkingly new piece of fundamental knowledge. Witness the tremendous activity that followed the discovery of deuterium. Practically every department of chemistry was busily engaged in some form of deuterium research within a few weeks. Little more came out of this vast effort than would have resulted from a centralized research.

I believe it is the purpose of our patent system to stimulate competitive research on applied subjects. Yet, there are countless minor researches under way all the time in various laboratories that have no direct commercial value, that might very well be centralized, with excellent results and considerable savings. Call it "cooperative" or by any name you please, it should be encouraged. Duplication of effort is not always the result of competitive laboratories not knowing what the other is doing. Sometimes it occurs within the confines of a single laboratory and within the supervision of a single director. Sometimes it is accidental and sometimes the rapid solution of some critical problem is so necessary that management is justified in setting two or more groups at work on it at the same time. Usually it is well to have the different groups attack it from different viewpoints. It is a situation, however, that requires skillful management, or the result may be disastrous. As long as esprit de corps can be maintained with, perhaps, the stimulation of friendly competition, all is well; but once personal jealousies have developed stagnation rather than progress is likely to result. It is essentially a problem of personnel management.

Tell the Public

I should like to close with the suggestion that better public relations be developed by industrial research in general. Many of the difficulties that have been placed in the way of industrial research resulted from an ignorance on the part of the public and even of men in high places as to what it was all about. Ignorance breeds fear and fear motivates destruction. I am advocating that industrial research itself improve its public acceptance—not that industrial units merely advertise their own research departments. In fact this latter activity may be deleterious to the desired effect. Advertising copy has a way of romanticizing research, putting an air of mystery around the laboratory, calling it a "home of magic" or some other equally intriguing name. By these means the public is led to believe that industrial research is beyond their understanding and what the public does not understand it fears.

The public should be told just what research is when used by industry and how it benefits mankind. Then too, as little secrecy as possible should be placed around new fundamental knowledge. It must be recognized that lacking any legal means of protecting its use, except secrecy, that some secrecy is quite proper, but let it be as little as possible. Publish as soon as is compatible with safety and notify the public of this through the daily press and keep in mind what Dr. Charles F. Kettering once said "When you lock the laboratory door, you lock out more than you lock in."

Forums Will Discuss Knock-Test Equipment

A series of regional forums to discuss operation and maintenance problems of knock-test equipment for motor and aviation gasolines will be held throughout the country, starting November 27, the Coordinating Research Council, Inc., has announced.

The forums are planned to provide practical assistance in helping overcome operating difficulties. One of the features of the meetings will be a series of slides on "what not to do." Information on changes in equipment and modern operating techniques will be discussed and ideas which have proved useful in one laboratory will be shared with others.

Schedule for the forums:

November 27-28, Sylvania Hotel, Philadelphia, J. E. Taylor, Gulf Research & Development Company, leader.

November 30-December 1, Palmer House, Chicago, J. O. Eisinger, Standard Oil Company (Indiana), leader.

December 4-5, President Hotel, Kansas City, H. M. Trimble, Phillips Petroleum Company, leader.

December 7-8, Rice Hotel, Houston, A. R. Stark, Humble Oil & Refining Company, leader.

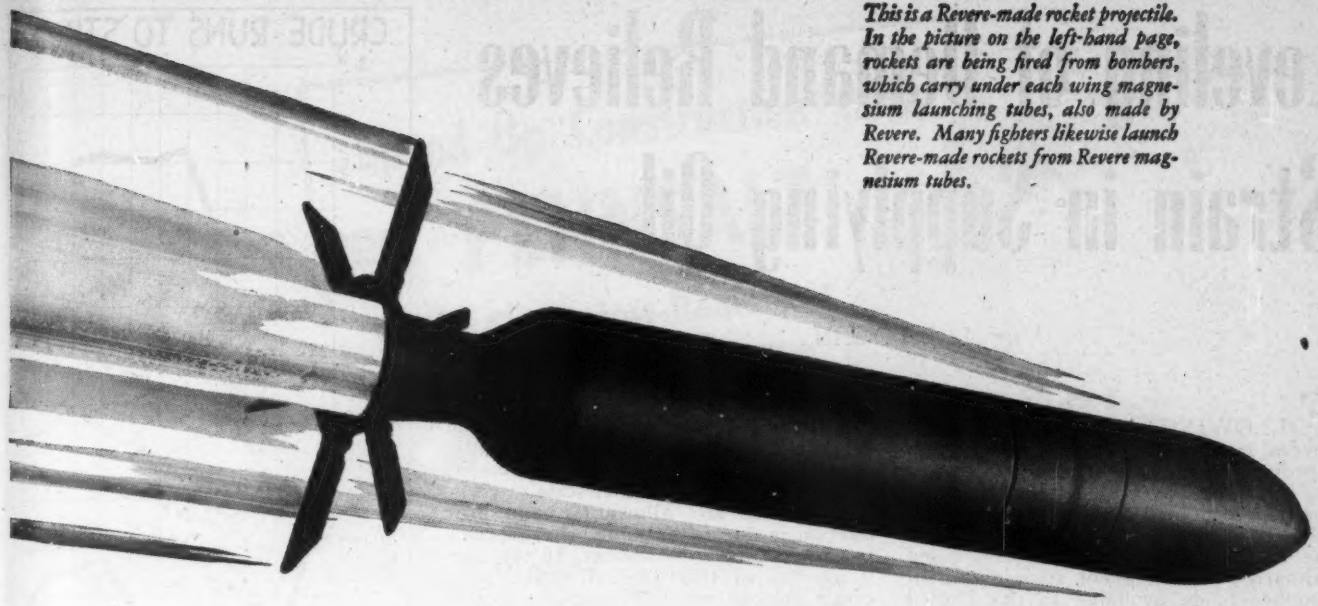
December 11-12, Richfield Oil Corporation, Wilmington, California, H. A. Mason, General Petroleum Corporation, leader.

December 14-15, California Research Corporation, Richmond, California, J. T. Ronan, Shell Oil Company, leader.

These forums, which have the approval of the Petroleum Administration for War, were authorized by the Coordinating Fuel Research Committee, and are under the joint sponsorship of Dr. A. E. Becker, Standard Oil Development Company, director of operation and maintenance projects of the CFR Motor Fuels Division, and J. G. Moxey, Jr., Sun Oil Company, leader of the operation and maintenance group working on laboratory detonation projects of the CFR Aviation Fuels Division. Assisting in the conduct of the forums will be representatives of Waukesha Motor Company, the manufacturer of the CFR knock-testing equipment, and a group of men who have had wide experience in knock-test work.

The agenda for the forums provides for a discussion of the two procedures in general use for testing motor gasolines (CFR Research Test Procedure for Determining Knock Characteristics of Motor Gasolines—CRC Designation F-1; CFR Motor Test Procedure for Determining Knock Characteristics of Motor Fuels—CRC Designation F-2) and one procedure used for testing aviation gasolines (CFR Lean Mixture Test Procedure for Determining Knock characteristics of Aviation Fuels — CRC Designation F-3) on the morning of the first day. The afternoon will be devoted to a question-and-answer period on these procedures, with the exception that in the discussion of the F-3 procedure, for reasons of military security, questions concerning testing aviation gasolines above 100 octane number are excluded. Both sessions of the first day are open to all interested in the operation and maintenance of knock-test equipment.

The second day will be devoted to the discussion of problems relative to the CFR Supercharge Method of Test for Knock Characteristics of Aviation Fuels (CRC Designation F-4), and the Lean Mixture procedure insofar as it relates to testing aviation gasolines above 100 octane number, and an inspection trip to a well-equipped laboratory. Attendance at this meeting is limited to representatives of laboratories operating F-4 engines, or F-3 engines used to test aviation gasolines above 100 octane number.



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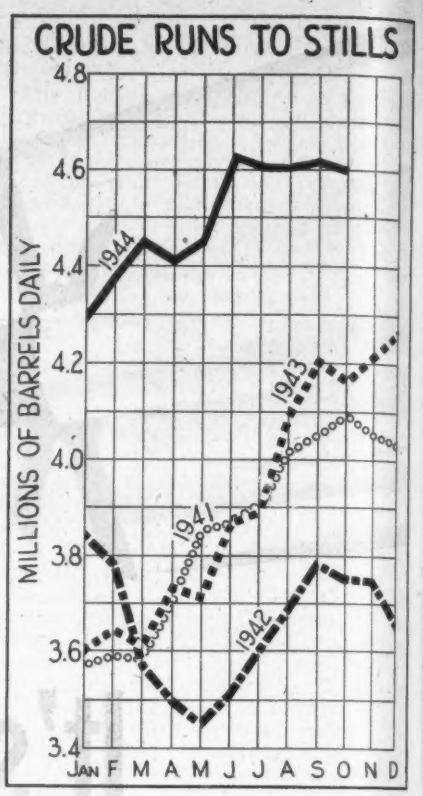
Leveling of Demand Relieves Strain in Supplying Oil

L. J. LOGAN



FOLLOWING the critical period of several months after invasion of western Europe, there has been some easing of the strain on the oil industry in meeting the unprecedented requirements of crude oil and products. This improvement of the industry's situation has been based primarily on the recent stepping up of supplies made available to the United Nations from the Caribbean area, where both producing and refining capacity have been expanded.

Through benefit of increased supplies of foreign oils, there has been possible a slight cut-back and subsequent leveling out of domestic crude production and domestic crude runs to stills. Previously, in the several months after D-Day, United States crude production was pushed up to an all-time high, and numerous fields of the country were being produced at rates in excess of maximum efficient levels, and refineries were operated at rates which could not be sustained regularly.

United States fields still are producing at higher rate than would be resorted to normally, for under usual conditions, reserves would have been kept better abreast of demand for crude. However, the situation on producing ability in relation to demand now appears better, not only because of the relief afforded by foreign supplies but also by the present intensified drilling in the United States, which holds promise of fair results henceforth in finding new fields and further developing existing fields.

Similarly, there has been some easing of the strain on domestic refineries, not only by increased availability of foreign refined products but also by the placing into operation of some additional refining capacity in the United States, in the concluding phase of the refinery expansion program.

Highest production of crude oil in the United States so far recorded or in prospect occurred during September, when the average was 4,756,000 barrels daily. In October, output was slightly lower, under reduced federal and state government quotas and allowables, and production is due to be under the September peak also in November. In the first 9 months of this year, United States crude output was 13 percent greater than in the corresponding months last year and 21 percent above the like period of 1941, last prewar year for the country. Of the increase in production this year over last year, Texas has furnished 92 percent, and of the increase for 1944 over 1941, Texas has supplied 84 percent. In making possible the sharp expansion of the supply of crude available to the nation, Texas producers turned out at their wells in the first 9 months of this year 32 percent more crude than in the like months of 1943 and approximately 50 percent more than in January-September, 1941. Some other states also have steadily expanded production, although less spectacularly than Texas. These include California, up 9 percent over last year and 35 percent over 1941; Louisiana, up 6 percent over last year and 15 percent over 1941; and sustained increases in Arkansas, Colorado, Kentucky, and Montana. New Mexico also has gone into new high ground, although production in 1943 was less than in 1941. Seven states increased in 1943 over 1941 but have not sustained last year's rate in 1944; they include Kansas, Michigan, Mississippi, New York, Ohio, Oklahoma, Wyoming. Several states have the unfavorable records of having produced less in 1944 than in either 1943 or 1941, having steadily declined; they include

Stocks of Crude Petroleum in U. S. by Grades, on October 1, 1941-1944

(Based on Weekly Report of U. S. Bureau of Mines)

THOUSANDS OF BARRELS

Grade or Origin	STOCKS, OCTOBER 1			
	1941	1942	1943	1944
Pennsylvania Grade	3,880	3,193	2,618	2,357
Other Appalachian	1,443	1,401	1,510	1,518
Lima-Michigan	996	1,552	1,049	910
Illinois-Indiana	19,302	10,348	11,399	15,179
Arkansas	2,794	2,599	2,814	2,866
Kansas	7,900	6,854	8,262	8,522
Louisiana	12,402	13,299	13,488	12,709
Northern	4,159	4,624	4,452	3,192
Gulf Coast	8,243	8,675	9,036	9,517
Mississippi	1,912	1,423	1,185	1,064
New Mexico	7,053	5,874	8,140	6,655
Oklahoma	53,712	43,861	35,208	30,699
Texas	81,788	101,430	102,759	108,371
East Texas	20,024	24,628	22,870	20,299
West Texas	17,152	24,295	23,267	31,446
Gulf Coast	24,510	28,290	31,198	29,450
Other Texas	20,102	24,217	25,424	27,176
Panhandle	.....	4,567	6,271	6,216
North	.....	7,036	5,805	6,238
South	.....	4,874	4,914	6,254
Other	.....	7,740	8,434	8,468
Rocky Mountain	15,646	14,822	12,760	7,458
California	34,870	34,772	32,814	22,167
Foreign	2,663	210	542	1,915
Total gasoline bearing in United States	246,361	241,638	234,548	222,390
Heavy in California	10,314	10,212	8,792	6,661
Total U. S.	256,675	251,850	243,340	229,051

U. S. Crude Runs to Stills and Percent of Refinery Capacity Used, by Districts, September and First 9 Months

Runs from Bureau of Mines, except September, 1944, from American Petroleum Institute; Capacities from American Petroleum Institute

THOUSANDS OF BARRELS

REFINING DISTRICT	CRUDE RUNS IN SEPTEMBER							REFINING CAPACITY AND USE, SEPTEMBER						TOTAL AMOUNT CRUDE RUN TO STILLS, FIRST 9 MONTHS			
	Total Amount Run				Daily Average Run			Daily Capacity			Percent Capacity Used						
	Sept., 1941	Sept., 1943	Sept., 1944	% Dif. '43-'44	Sept., 1941	Sept., 1943	Sept., 1944	Sept., 1941	Sept., 1943	Sept., 1944	Sept., 1941	Sept., 1943	Sept., 1944	9 Months 1941	9 Months 1943	9 Months 1944	% Dif. '43-'44
East Coast, Texas Inland, Texas Gulf, La. Gulf, Ark., and La. Inland	62,803	63,383	73,722	+16.3	2,093	2,113	2,457	2,284	2,444	2,518	91.6	86.5	97.6	533,341	488,651	640,126	+30.9
Appalachian	4,650	4,702	4,810	+ 2.3	155	157	160	166	177	177	93.4	88.7	90.4	39,865	41,850	42,182	+ .8
Indiana, Illinois, Kentucky, etc	22,076	22,399	22,490	+ .4	736	746	750	752	824	824	97.9	90.5	91.0	184,621	196,638	207,485	+ 5.5
Oklahoma, Kansas, Missouri	11,116	10,300	11,240	+ 9.1	371	343	375	413	416	418	89.8	82.5	89.7	94,311	92,728	98,534	+ 6.3
Rocky Mountain	3,273	3,380	3,617	+ 7.0	109	113	121	136	147	154	80.1	76.9	78.6	25,152	25,888	30,331	+17.2
California	17,563	21,924	23,169	+ 5.7	585	731	772	787	817	817	74.3	89.5	94.5	158,606	196,418	216,731	+10.3
Total United States	121,481	126,088	139,048	+10.3	4,049	4,203	4,635	4,538	4,825	4,908	89.2	87.1	94.4	1,035,896	1,042,173	1,235,389	+18.5

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Products Held by Refiners in United States at End of September

Stocks at refineries, at bulk terminals, in transit, and in pipe lines. Data for 1941 and 1943 from Bureau of Mines monthly reports; for 1944 from weekly reports of American Petroleum Institute.

THOUSANDS OF BARRELS

DISTRICT	FINISHED AND UNFINISHED GASOLINE Stocks End of September			KEROSINE Stocks End of September			GASOIL AND DISTILLATE FUEL Stocks End of September			RESIDUAL FUEL OIL Stocks End of September		
	1941	1943	1944	1941	1943	1944	1941	1943	1944	1941	1943	1944
East Coast, Texas Gulf, La. Gulf, N. La., Ark., and Inland Texas	37,687	29,773	35,835	7,798	6,820	10,143	29,219	18,176	24,658	22,514	18,153	22,292
Appalachian	3,477	2,353	3,559	302	336	415	801	895	668	639	422	439
Indiana, Illinois, Kentucky	15,430	14,089	16,334	1,757	2,240	2,621	6,058	6,101	6,327	4,468	3,409	4,055
Oklahoma, Kansas, Missouri	6,993	5,910	6,814	690	821	833	2,150	2,024	2,037	2,067	1,561	1,574
Rocky Mountains	1,373	1,125	1,580	109	71	114	332	410	416	538	701	698
California	15,003	15,969	13,906	1,006	622	457	12,852	12,075	11,223	53,526	33,731	28,507
Total United States	79,963	69,219	78,028	11,662	10,910	14,583	51,412	39,681	45,329	83,752	57,977	57,565

Illinois, Indiana, Nebraska, Pennsylvania, West Virginia.

In spite of record-breaking United States crude production, the heavy requirements have necessitated drawing on stocks besides using current domestic supply and lately increased imports. The national inventory of crude remains close to the recently reached 23-year low, stocks of refinable crude having stood at 222,390,000 barrels at the end of September and being still around that same level. The crude stocks are about 24,000,000 barrels lower than at this time of 1941, one half of the national draft having occurred in California and the other half east of California. The latter reduction is the net result of a heavy decrease in stocks of Oklahoma grade and declines in Illinois-Indiana, Mississippi, Pennsylvania, and Rocky Mountain crudes, which have been only partly offset by increases in grades produced in Texas, Kansas, Louisiana, Arkansas.

Runs to Stills

Crude runs to stills were steadily increased in the earlier months of this year, in reflection of the completion of new refining facilities, until they reached an all-time peak of 4,665,000 barrels daily in June, and they have been maintained fairly close to that record level ever since. Runs to stills were slightly higher in 1943 than in 1941, although curves for the two years almost coincided; but the trend for this year has been sharply above the old curves. In the first 9 months of 1944, the amount of crude run to stills was 18.5 percent greater than that run in the like period of 1943 and 19.2 percent above 1941. In spite of changes in crude producing ability of the various states, there has been efficient mobilization of transportation facilities and lining up of crude supplies for individual plants, with the result that all major refining districts have processed more crude this year than ever before. In September, the amount of crude charged to stills represented 94.4 percent of the rated capacity of the nation's refineries, with plants in practically all refining districts operating around or above 90 percent of potential. As compared with the 94.4 percent rate for the nation in September of this year, capacity was utilized only to the extent of 87.1 percent in September, 1943, and 89.2 percent in September, 1941. The present high rate reflects the extreme and successful efforts to minimize shutdown time.

Demand Higest on Record

The gains of 13 and 18 percent in crude production and crude runs to stills this year reflect a comparable increase in demand for all oils, which is breaking all previous records. Based on domestic production of crude and natural gasoline and net change in stocks of crude, natural gasoline, and products, total demand for all oils was over 11 percent greater for the first 9 months of this year than in the like period last year, and the corresponding increase for September was nearly 6 percent. These figures do not take into consideration imports, because of censorship, but it is generally known that imports are running substantially higher this year than last year, involving primarily crude and heavy fuel oil. Therefore, this year's increase in total

Refinery Production of Major Products and Percent Yield from Crude Run, by Districts

Results in September and first 9 months, 1944, compared with those in like periods last year and in 1941, last pre-war year for U. S. Table based on Bureau of Mines statistics, except data for September, 1944, estimated with aid of A.P.I. weekly bulletins.

THOUSANDS OF BARRELS

DISTRICT	*Gasoline			Kerosine			Distillate Fuel Oil			Residual Fuel Oil			Lubricants		
	1941	1943	1944	1941	1943	1944	1941	1943	1944	1941	1943	1944	1941	1943	1944
East Coast, Texas Gulf, La. Gulf, North La., Ark., and Inland Texas															
Production, September	28,604	25,443	30,293	3,877	3,460	3,941	9,934	11,640	12,149	14,124	17,127	18,554	1,884	1,655	1,843
(Daily Average)	953.5	848.1	1,009.8	129.2	115.3	131.4	331.1	388.0	405.0	470.8	570.9	618.5	62.8	55.2	61.4
Percent Yield from Crude	42.0	35.3	36.5	6.2	5.5	5.3	15.8	18.4	16.5	22.5	27.0	25.2	3.0	2.6	2.5
Production, Jan.-Sept.	240,171	195,918	262,130	34,085	30,375	36,830	82,159	82,324	109,312	125,280	133,391	166,546	15,538	14,620	16,516
(Daily Average)	879.8	717.6	956.7	124.8	111.3	134.4	300.9	301.6	398.9	458.9	488.6	607.8	56.9	53.6	60.2
Appalachian															
Production, September	2,240	1,980	2,018	269	301	324	398	575	478	676	787	698	544	498	433
(Daily Average)	74.7	66.0	67.3	9.0	10.0	10.8	13.3	19.2	15.9	22.5	26.2	23.3	18.1	16.6	14.1
Percent Yield from Crude	47.2	41.3	41.3	5.8	6.4	6.7	8.6	12.2	9.9	14.5	16.7	14.5	11.7	10.6	8.8
Production, Jan.-Sept.	18,999	16,533	17,962	2,389	2,876	2,969	3,628	4,972	4,659	5,821	8,243	6,887	4,755	4,257	3,915
(Daily Average)	69.6	60.6	65.6	8.8	10.5	10.8	13.3	18.2	17.0	21.3	30.2	25.1	17.4	15.6	14.2
Indiana, Illinois, Kentucky															
Production, September	12,568	11,124	11,789	1,056	1,095	1,132	2,235	2,859	2,308	3,872	4,755	4,748	376	370	315
(Daily Average)	418.9	370.8	393.0	35.2	36.5	37.7	74.5	95.2	76.9	129.1	158.5	158.3	12.5	12.3	10.5
Percent Yield from Crude	53.9	46.4	49.3	4.8	4.9	5.0	10.1	12.8	10.3	17.5	21.2	21.1	1.7	1.7	1.4
Production, Jan.-Sept.	100,996	92,058	105,081	8,704	10,755	10,357	19,456	25,912	25,425	34,613	45,470	42,736	3,097	3,390	3,287
(Daily Average)	369.9	337.2	383.3	31.9	39.4	37.7	71.3	94.9	92.7	126.8	166.5	156.0	11.3	12.4	12.0
Oklahoma, Kansas, Missouri															
Production, September	6,361	5,436	6,177	553	608	554	1,191	1,279	1,664	1,941	1,800	2,035	348	401	360
(Daily Average)	212.0	181.2	205.9	18.4	20.3	18.4	39.7	42.6	55.4	64.7	60.0	67.8	11.6	13.4	12.0
Percent Yield from Crude	52.9	48.6	50.9	5.0	5.9	4.9	10.7	12.4	14.8	17.5	17.5	18.1	3.1	3.9	3.2
Production, Jan.-Sept.	52,226	43,980	50,372	5,646	6,398	5,916	9,940	13,196	14,162	16,488	19,146	17,665	2,885	3,237	3,297
(Daily Average)	191.5	161.1	183.8	20.7	23.4	21.6	36.4	48.3	51.7	60.4	70.1	64.5	10.6	11.8	12.0
Rocky Mountain															
Production, September	1,601	1,525	1,678	81	54	68	265	338	399	645	819	936	8	24	25
(Daily Average)	53.4	50.8	55.9	2.7	1.8	2.3	8.8	11.3	13.3	21.5	27.3	31.2	.3	.8	.9
Percent Yield from Crude	45.0	43.5	43.2	2.5	1.6	1.9	8.1	10.0	11.0	19.7	24.2	25.8	.2	.7	.7
Production, Jan.-Sept.	13,242	11,987	14,529	663	595	634	2,092	2,751	3,322	5,421	7,419	8,139	122	179	190
(Daily Average)	48.5	43.9	53.0	2.4	2.2	2.3	7.7	10.1	12.1	19.9	27.2	29.7	.5	.6	.7
California															
Production, September	7,614	8,139	8,747	113	299	197	2,001	1,832	2,583	6,680	11,322	11,082	267	288	324
(Daily Average)	253.8	271.3	291.6	3.8	10.0	6.6	66.7	61.1	86.1	228.7	377.4	369.4	8.9	9.6	10.8
Percent Yield from Crude	35.9	31.0	32.1	0.6	1.4	0.8	11.4	8.4	11.1	39.1	51.6	47.8	1.5	1.3	1.4
Production, Jan.-Sept.	63,319	66,794	80,564	1,619	2,631	2,034	21,915	22,511	23,118	64,708	94,363	99,662	2,487	2,555	2,886
(Daily Average)	231.9	244.7	294.0	5.9	9.6	7.4	80.3	82.5	84.4	237.0	345.9	363.7	9.1	9.4	10.6
Total United States															
Production, September	58,988	53,647	60,702	5,949	5,817	6,216	16,024	18,523	19,581	28,119	36,610	35,053	3,427	3,236	3,290
(Daily Average)	1,966.3	1,788.2	2,023.4	198.3	193.9	207.2	534.1	617.4	652.7	937.3	1,220.3	1,168.4	114.2	107.9	109.7
Percent Yield from Crude	44.6	38.1	39.4	4.9	4.6	4.5	13.2	14.7	15.8	23.1	29.0	25.2	2.8	2.6	2.4
Production, Jan.-Sept.	488,953	427,270	530,588	53,106	53,630	58,740	139,190	151,666	179,998	252,331	308,032	338,635	28,884	28,238	30,098
(Daily Average)	1,791.0	1,623.1	1,936.4	194.5	196.4	214.4	509.9	555.6	656.9	924.3	1,128.3	1,235.9	105.8	103.4	109.8

* Production includes straight run, cracked, and natural blended at refineries. Yield indicates percent of crude runs made into straight run and cracked gasoline.

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PRESSURE VESSELS
RECEIVERS
STILLS
TANKS

Production, Changes in Stocks, and Demand for Crude and Products

Bureau of Mines figures except September, 1944, estimated with aid of A.P.I. Bulletins. (Thousands of Barrels)

ITEM	SEPTEMBER					FIRST 9 MONTHS				
	1941	1942	1943	1944	% Dif. '43-'44	1941	1942	1943	1944	% Dif. '43-'44
ALL OILS										
Domestic Production, Total	126,641	123,100	138,109	151,228	+ 9.5	1,085,154	1,092,559	1,164,535	1,317,855	+ 13.2
(Daily Average)	4,221	4,103	4,604	5,041	+ 9.5	3,975	4,002	4,266	4,810	+ 12.8
Crude Oil	119,320	115,933	130,407	142,678	+ 9.4	1,024,420	1,029,258	1,097,875	1,242,818	+ 13.2
Natural Gasoline	7,057	6,967	7,702	8,550	+ 11.0	58,198	61,504	66,660	75,037	+ 12.6
Benzol	264	200				2,536	1,797			
Imports, Total	10,093					68,664				
Crude	4,662					36,334				
Refined	5,431					32,330				
Change in Stocks	+197	—1,591	+324	+5,558		—18,441	—43,830	—16,571	+1,297	
Stocks Beginning of Period	544,639	514,186	481,045	479,793	— 0.3	563,277	556,425	497,940	484,054	— 2.9
Stocks End of Period	544,836	512,595	481,369	485,351	+ 0.8	544,836	512,595	481,369	485,351	+ 0.8
(Days' Supply)	129	123	105	100	— 4.8	135	123	111	101	— 9.0
Refinable Crude	246,731	240,588	236,287	222,390	— 5.9	246,731	240,588	236,287	222,390	— 5.9
Heavy Crude in Calif.	10,321	10,167	8,905	6,661	— 25.2	10,321	10,167	8,905	6,661	— 25.2
Natural Gasoline	5,373	6,056	4,723	4,100	— 13.2	5,373	6,056	4,723	4,100	— 13.2
Refined Products	282,411	255,784	231,454	252,200	+ 9.0	282,411	255,784	231,454	252,200	+ 9.0
Demand, excl. of imports	126,641	124,691	137,785	145,670	+ 5.7	1,103,595	1,136,389	1,181,106	1,316,558	+ 11.5
(Daily Average)	4,221	4,156	4,593	4,856	+ 5.7	4,042	4,163	4,326	4,805	+ 11.1
Demand, incl. of imports	136,537					1,172,259				
CRUDE OIL—										
Demand by Source—										
Domestic Production	119,320	115,933	130,407	142,678	+ 9.4	1,024,420	1,029,258	1,097,875	1,242,818	+ 13.2
(Daily Average)	3,977	3,864	4,347	4,756	+ 9.4	3,752	3,770	4,022	4,536	+ 12.8
Imports	4,662					36,334				
Change in Stocks, Refinable	—3,519	—4,082	—798	—1,511		—17,978	—6,911	+1,398	—19,372	
Stocks, Beginning of Period	250,240	244,670	237,085	223,901	— 5.6	264,709	247,499	234,889	241,762	+ 2.9
Stocks, End of Period	246,731	240,588	236,287	222,390	— 5.9	246,731	240,588	236,287	222,390	— 5.9
(Days' Supply)	60	60	54	46	— 14.8	65	63	59	48	— 18.6
Demand, excl. of imports	122,839	120,015	131,205	144,189	+ 9.9	1,042,398	1,036,169	1,096,476	1,262,190	+ 15.1
(Daily Average)	4,095	4,000	4,373	4,806	+ 9.9	3,818	3,795	4,016	4,607	+ 14.7
Demand, incl. of imports	127,501					1,078,732				
Demand by Use—										
Run to Stills, Total	121,481	113,474	126,088	139,048	+ 10.3	1,035,896	992,012	1,042,173	1,235,389	+ 18.5
(Daily Average)	4,049	3,782	4,203	4,635	+ 10.3	3,794	3,634	3,817	4,509	+ 18.1
Domestic	116,994	113,228	123,872	134,548	+ 8.6	999,291	977,841	1,037,762	1,203,932	+ 16.0
Foreign	4,487	246	2,216	4,500	+ 103.1	36,605	14,171	4,411	31,457	+ 613.1
Exports	2,900	7,316	7,965	6,800	— 14.6	25,722	56,033	60,647	57,000	— 6.0
Transfers to fuel oil stocks, used as fuel, losses	3,731					18,699				
Demand, excl of exports	125,212					1,054,595				
Demand, incl. of exports	128,112	120,790	134,053	145,848	+ 8.8	1,080,317	1,048,045	1,102,820	1,292,389	+ 17.2
(Daily Average)	4,270	4,026	4,468	4,862	+ 8.8	3,957	3,839	4,040	4,717	+ 16.8
MOTOR FUEL										
Production, Total	61,067	49,558	54,847	62,183	+ 13.4	511,253	458,097	440,828	545,837	+ 23.8
(Daily Average)	2,036	1,652	1,828	2,073	+ 13.4	1,873	1,678	1,615	1,992	+ 23.4
Imports	105					261				
Change in Stocks	—1,071	—2,459	—1,648	—1,359		—5,513	—15,247	—11,495	—111	
Stocks, beginning of period	79,205	77,808	65,557	70,753	+ 7.9	83,647	90,596	75,404	69,505	— 7.8
Finished Gasoline	73,094	71,403	60,664	66,542	+ 9.7	77,943	86,159	70,772	64,964	— 8.2
Natural Gasoline	6,111	6,405	4,893	4,211	— 13.9	5,704	4,437	4,632	4,541	— 2.0
Stocks, End of period	78,134	75,349	63,909	69,394	+ 8.6	78,134	75,349	63,909	69,394	+ 8.6
(Days' Supply)	38	43	34	33	— 2.9	41	43	39	35	— 10.3
Finished Gasoline	72,761	69,293	59,186	65,294	+ 10.3	72,761	69,293	59,186	65,294	+ 10.3
Natural Gasoline	5,373	6,056	4,723	4,100	— 13.1	5,373	6,056	4,723	4,100	— 13.1
Demand, excl. small imports	62,138	52,017	56,495	63,542	+ 12.5	516,766	473,344	45,323	545,948	+ 20.7
(Daily Average)	2,071	1,734	1,883	2,118	+ 12.5	1,893	1,734	1,657	1,992	+ 20.2
GASOLINE—Finished										
Production (Straight run, cracked, natural blended)	58,988	48,078	53,647	60,702	+ 13.1	488,953	441,031	427,270	530,588	+ 24.2
(Daily Average)	1,966	1,602	1,788	2,023	+ 13.1	1,791	1,615	1,561	1,936	+ 24.0
Pct. yield, str. run, cracked	44.6	37.9	38.1	39.4		43.9	40.3	36.7	39.0	
Imports						261				
Change in Stocks, Finished	—333	—2,110	—1,478	—248		—5,182	—16,866	—11,586	+330	
Stocks, beginning of period	73,094	71,403	60,664	65,542	+ 9.7	77,943	86,159	70,772	64,964	— 8.2
Stocks, end of period	72,761	69,293	59,186	65,294	+ 10.3	72,761	69,293	59,186	65,294	+ 10.3
(Days' Supply)	36	41	32	32		40	41	37	34	— 8.1
Demand, excl. small imports	59,321	50,188	55,125	60,950	+ 10.6	494,135	457,897	438,856	530,258	+ 20.8
(Daily Average)	1,977	1,673	1,837	2,032	+ 10.6	1,810	1,677	1,608	1,935	+ 20.3
KEROSINE										
Production	5,949	5,421	5,817	6,216	+ 6.8	53,106	50,457	53,630	58,740	+ 9.5
(Daily Average)	198	181	194	207	+ 6.8	194	185	196	214	+ 9.5
Percent yield from crude	4.9	4.8	4.6	4.5		5.1	5.1	5.1	4.8	
Imports						124				
Change in Stocks	+26	+187	+624	+1,244		+2,150	—2,152	+846	+5,224	
Stocks, beginning of period	11,636	12,176	10,286	13,339	+ 29.7	9,512	14,515	10,064	9,359	— 7.0
Stocks, end of period	11,662	12,363	10,910	14,583	+ 33.7	11,662	12,363	10,910	14,583	+ 33.7
(Days' Supply)	58	71	63	88	+ 39.7	51	64	57	75	+ 31.6
Demand, excl. small imports	5,923	5,234	5,193	4,972	— 4.2	50,956	52,609	52,784	53,516	+ 1.4
(Daily Average)	197	174	173	166	— 4.2	187	193	193	195	+ 1.0
DISTILLATE FUEL OIL										
Production	16,024	18,062	18,523	19,581	+ 5.7	139,190	142,221	151,666	179,998	+ 18.7
(Daily Average)	534	602	617	653	+ 5.7	510	521	556	657	+ 18.2
Percent yield from crude	13.2	15.9	14.7	15.8		13.4	14.3	14.6	14.6	
Transfers from Crude	210	217	261	255	— 2.3	1,856	1,810	2,227	2,395	+ 7.5
Imports	814					3,790				
Change in Stocks	+4,249	+2,899	+2,750	+4,617		+8,501	—3,513	—5,259	+3,611	
Stocks, beginning of period	47,163	42,918	36,931	40,712	+ 10.2	42,911	49,330	44,940	41,718	— 7.2
Stocks, end of period	51,412	45,817	39,681	45,329	+ 14.2	51,412	45,817	39,681	45,329	+ 14.2
(Days' Supply)	129	89	74	89	+ 20.3	106	85	68	70	+ 2.9
Demand, excl. of imports	11,985	15,380	16,034	15,219	— 5.1	132,545	147,544	159,152	178,782	+ 12.3
(Daily Average)	399	513	534	507	— 5.1	486	540	583	652	+ 11.8
Demand, incl. of imports	12,799					136,335				
RESIDUAL FUEL OIL										
Production	28,118	30,402	36,610	35,053	— 4.2	252,331	264,461	308,032	338,635	+ 9.9
(Daily Average)	937	1,013	1,220	1,168	— 4.2	924	969	1,128	1,236	+ 9.6
Percent yield from crude	23.1	26.8	29.0	25.2		24.4	26.7	29.6	27.5	
Transfers from crude	2,152	1,971	2,253	2,200	— 2.3	3,728	14,967	16,976	21,007	+ 23.7
Imports	4,327					25,400				
Change in Stocks	+1,484	+1,651	+1,120	+4,059		—4,274	—13,695	—3,806	+9,081	
Stocks, beginning of period	82,268	67,613	56,857	53,506	— 5.9	88,026	82,959	61,783	48,484	— 21.5
Stocks, end of period	83,752	69,264	57,977	57,565	— 0.7	83,752	69,264	57,977	57,565	— 0.7
(Days' Supply)	94	72	49	52	+ 6.1	89	68	51	45	— 11.8
Demand, excl. of imports	26,634	28,751	35,490	33,194	— 6.5	256,605	278,156	311,838	350,561	+ 12.4
(Daily Average)	888	958	1,183	1,106	— 6.5	940	1,019	1,142	1,279	+ 12.0
Demand, incl. of imports	30,961					282,005				

demand is higher than the mentioned 11 percnet when imports are considered.

Attesting the improvement this year in balancing supply with demand, stocks of all oils on September 30 were approximately the same as at the beginning of the year, whereas the first 9 months of the several preceding years required moderate to heavy withdrawals from storage—16 millions of barrels in 1943, 43 millions in 1942, 18 millions in 1941. In September of this year there was a 5,558,000-barrel accumulation in stocks of all oils, compared with virtually no September changes in 1943 and 1941 and a 1,591,000-barrel withdrawal in 1942. The maintenance of stocks this year has been characterized, however, by concurrent reduction of crude stocks in building up stocks of refined products, with runs to stills running exceptionally high in relation to crude production. In spite of the stabilizing of stocks, inventories are abnormally light in relation to the prevailing unprecedented demand, and the stocks of all oils on September 30 represented only 101 days' supply, on the basis of daily average demand in the first 9 months of this year. Stocks at the end of September in earlier years represented 111 days' supply in 1943, 123 days' in 1942, and 135 days' supply in 1941.

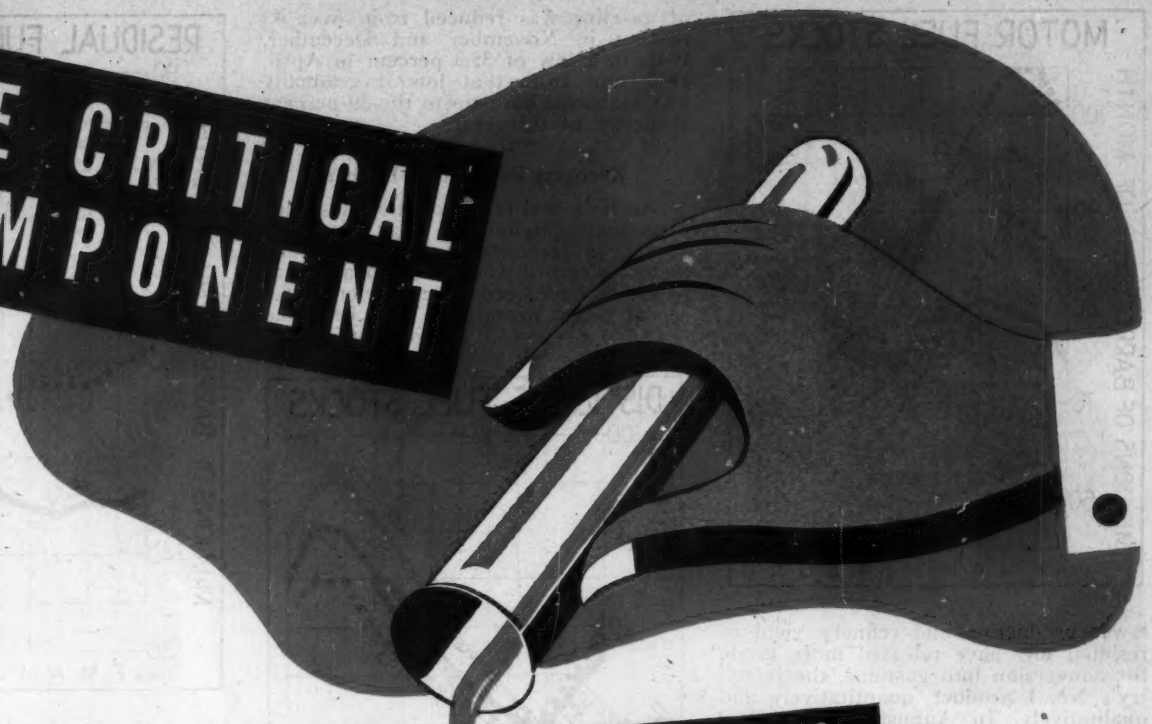
Refined Products

Unprecedented demand for all oils in the aggregate this year reflects record-breaking requirements of all of the major refined products, including gasoline, residual fuel oil, distillate fuel oil, and kerosine. In response to the high demand, production of these products has broken all previous records, and following earlier difficulties in meeting supply, there has been this year a restoration of relatively favorable inventory positions for the various products.

Noteworthy among trends for individual products are those involving motor fuel and residual fuel oil. In response to the highest trend of motor fuel production this year ever recorded, with output well above 2,000,000 barrels daily since last spring, the stocks of motor fuel were pushed above the 1943 curve at the beginning of summer and they subsequently have been maintained steadily several millions of barrels above the 1943 trend. Although they have remained about 10 millions of barrels under the 1941 trend, the motor fuel stocks have been comfortably adequate, with civilian supplies rationed. However, stocks are only about 9 percent above a year ago, whereas demand was nearly 21 percent greater in the first 9 months of this year than in the like period last year, and inventories now represent only 35 days' supply, against 39 days' supply held a year ago.

Data on residual fuel oil reflects especially the influence of the Caribbean area in taking over a large part of the burden of supplying requirements. Domestic production of residual fuel has been gradually lowered since the early part of this year, yet stocks have been steadily increased in an aggregate amount of over 10 millions of barrels from the war time low of last spring. In this upturn, the curve for 1944 recently reached and crossed above that for 1943. The gradual cut-back in production of residual fuel oil has permitted a steady cutting down of the yield of this lower-grade although highly important product at refineries, from 29 percent in January to 26 percent in August. Conversely, the

THE CRITICAL COMPONENT



RUST PREVENTIVE CHEMICALS

Each component of a compounded oil is manifestly a critical component. This is axiomatic. Yet, in every process, there is one component that is more critical than any other in its effect on the finished product.

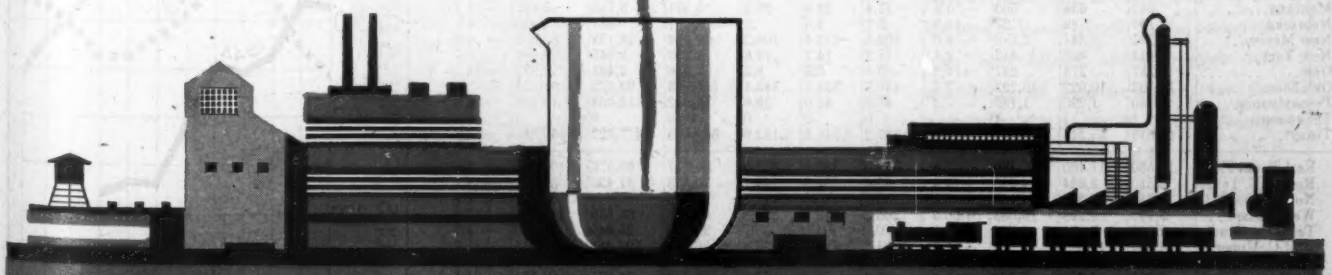
Take rust preventive oils, for instance. Of course, it is necessary to start with the right lubricating oil, but the really critical component is the base which is compounded with that oil.

Emery's X-234 meets these critical requirements. The active ingredients of this rust preventive base insure complete coverage of the metal and retention of this sealing surface even under adverse conditions. Any residual surface moisture is removed because the oil carrying X-234 actually creeps under such moisture and coats the metal.

The rust preventive oil, prepared by mixing Emery's X-234 with suitable lubricating oils, is designed to meet the requirements of the Co-operative Research Council's Designation L-7-443. This, and other Emery rust preventive bases, may be incorporated with waxes or other ingredients for the production of rust preventive coating compounds.

Oils treated to resist rust, and other metal-working compounds, are prepared by the manufacturers of lubricating specialties, using Emery bases, each designed in our laboratories for its special purpose and specific oil.

Write for detailed recommendation of the Emery base best suited for your particular need.



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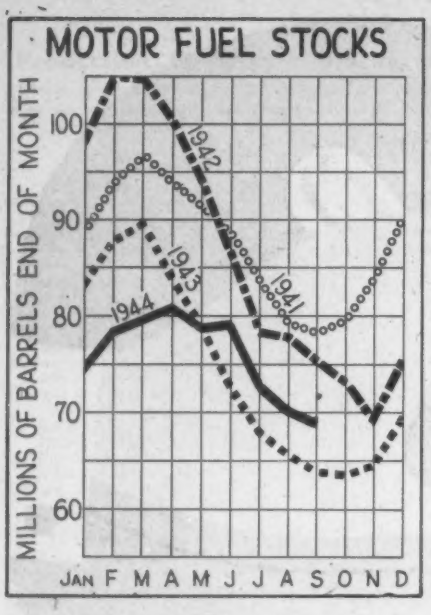
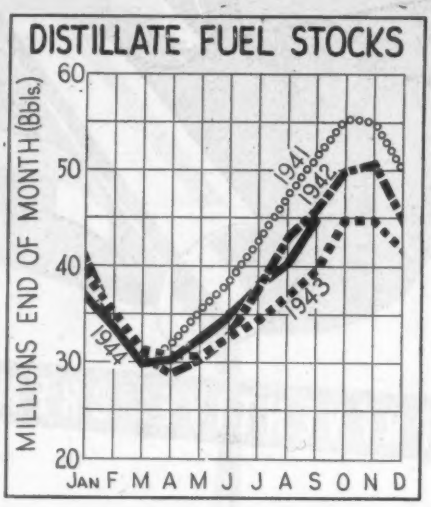
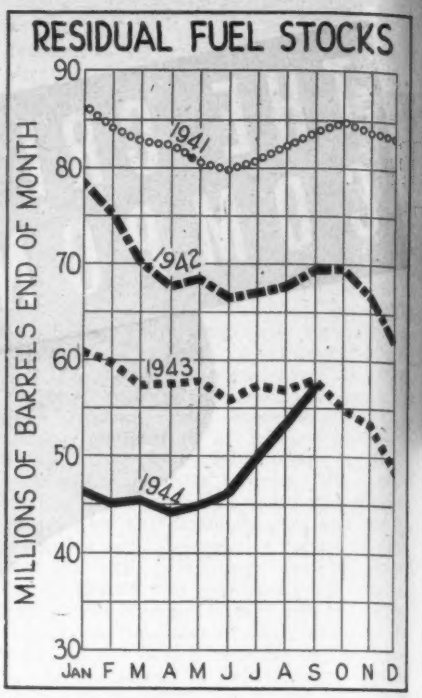


lower production and refinery yield of residual fuel have released more crude for conversion into gasoline, the industry's No. 1 product, quantitatively and qualitatively. In August, the yield of gasoline from crude run at United States refineries was 39.4 percent, slightly above yields around or below 39 percent in earlier months of the year. Under the war time heavy need for residual fuel and the rationing of gasoline, the yield of gasoline was reduced from over 45 percent in November and December, 1941, to a low of 35.3 percent in April, 1943, and from that low it gradually was increased back up to the 39 percent or better of this year.

Kerosine Production Higher

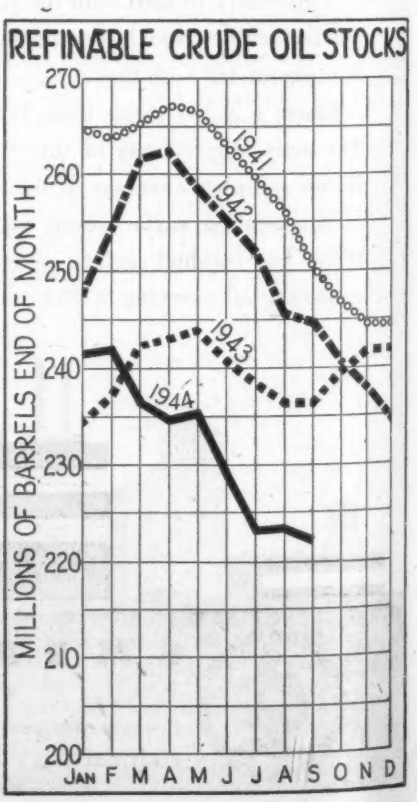
Distillate fuel oil production has been consistently higher this year than ever before, in response to the highest demand on record, and the seasonal trends of stocks have been close to average for recent years. Inventories have been and continue around 5 millions of barrels





lower than in 1941 but several millions of barrels higher than in 1943. The increase of stocks over last year has been about in line with the increase in prevailing demand, and on the basis of days' supply, inventories are about the same as a year ago. Yields of distillate fuel at refineries have continued comparatively large, that is, around 14.5 to 15 percent.

Demand for kerosine has shown practically no change during the past 3 years, having been a little higher than in 1941. But production has been nearly 10 percent higher this year than last year, and stocks have been increased, being now about 3,500,000 barrels higher than a year ago.



United States Production, September and First 9 Months

From U. S. Bureau of Mines, except September, 1944, estimated from A.P.I. weekly reports, and breakdowns of Texas by districts based on A.P.I. and Texas Railroad Commission reports.

THOUSANDS OF BARRELS

State or District	MONTH TOTAL, SEPTEMBER				DAILY AVERAGE IN SEPTEMBER			FIRST 9 MONTHS OF YEAR			
	1941	1943	1944	Percent Change '43-'44	1941	1943	1944	1941	1943	1944	Percent Change '43-'44
Alabama			9				.3			25	
Arkansas	2,226	2,285	2,423	+ 6.4	74.2	76.2	80.8	19,641	20,339	22,026	+ 8.3
California	19,403	23,424	26,467	+13.0	646.8	780.8	882.2	170,969	211,470	230,553	+ 9.0
San Joaquin Val.	8,022	11,105	12,397	+11.6	267.4	370.2	413.2	69,517	98,991	107,767	+ 8.9
Coastal District	2,731	3,333	4,380	+31.4	91.0	111.1	146.0	23,654	29,716	36,766	+23.8
L. A. Basin	8,650	8,986	9,690	+ 7.8	288.4	299.5	323.0	77,798	82,763	86,020	+ 3.9
Colorado	183	200	260	+30.0	6.1	6.7	8.7	1,308	1,699	2,132	+25.5
Florida			1							11	
Illinois	12,692	6,592	6,294	— 4.5	423.1	219.7	209.8	96,586	61,958	58,303	— 5.9
Indiana	532	434	406	— 6.5	17.7	14.5	13.5	5,033	4,028	3,805	— 5.5
Kansas	7,393	8,475	8,305	— 2.0	246.4	282.5	276.8	60,049	81,053	74,460	— 8.1
Kentucky	391	740	855	+15.5	13.0	24.7	28.5	3,615	5,676	6,756	+19.0
Louisiana	9,595	10,470	10,845	+ 3.6	319.8	349.0	361.5	84,529	91,467	96,851	+ 5.9
North Louisiana	1,996	2,157	2,192	+ 1.6	66.5	71.9	73.1	18,979	20,944	18,356	—12.4
South Louisiana	7,599	8,313	8,653	+ 4.9	253.3	277.1	288.4	65,550	70,523	78,495	+ 1.1
Michigan	1,545	1,729	1,485	—14.1	51.5	57.6	49.5	11,050	15,798	13,972	— 1.2
Mississippi	1,694	1,470	1,463	— .5	56.5	49.0	48.8	8,957	14,569	11,885	—18.4
Missouri	4	3	3		.1	.1	.1	35	27	27	
Montana	642	688	666	— 3.2	21.4	22.9	22.2	5,511	5,785	6,447	+11.4
Nebraska	166	49	27	—44.9	5.6	1.6	.9	1,161	531	313	— 4.1
New Mexico	3,285	3,341	3,186	— 4.6	109.5	111.4	106.2	29,064	28,158	30,000	+ 6.5
New York	445	423	413	— 2.4	14.8	14.1	13.8	3,838	3,845	3,588	— 6.7
Ohio	287	278	247	—11.2	9.6	9.3	8.2	2,456	2,493	2,232	—10.5
Oklahoma	13,102	10,022	10,292	+ 2.7	436.8	334.1	343.1	115,743	92,472	91,615	— .9
Pennsylvania	1,440	1,290	1,189	— 7.8	48.0	43.0	39.6	12,352	12,068	10,884	— 9.8
Tennessee	1	1	1		.0	.0	.0	9	9	9	
Texas*	41,616	55,314	64,587	+16.8	1,387.2	1,843.8	2,152.9	369,675	417,222	550,685	+32.0
East Texas Field	10,560	11,400	11,130	— 2.4	352.0	380.0	371.0	96,157	93,573	100,895	+ 7.8
Rest of E. Texas	2,550	3,924	4,490	+14.4	85.0	130.8	149.7	20,813	31,426	36,591	+16.4
North Texas	3,985	4,218	4,435	+ 5.1	132.8	140.6	147.8	35,913	37,046	39,931	+ 7.8
West Texas	7,986	9,998	15,083	+50.9	266.2	333.3	502.8	66,098	64,639	114,768	+77.6
Texas Panhandle	2,407	3,120	2,961	— 5.1	80.2	104.0	98.7	20,049	25,049	25,980	+ 3.7
Gulf C. Upper	8,451	14,541	16,275	+11.9	281.7	484.7	542.5	66,709	104,488	143,915	+37.7
Gulf C. Lower	3,648	5,079	7,264	+43.0	121.6	169.3	242.2	32,708	35,272	57,759	+63.8
Southwest Texas	2,203	2,247	2,368	+ 5.4	73.4	74.9	78.9	19,579	16,075	21,131	+31.5
S. Central Texas	604	570	580	+ 1.8	20.1	19.0	19.3	5,432	4,646	5,396	+16.1
Utah								3	4		
West Virginia	289	274	261	— 4.7	9.6	9.1	8.7	2,550	2,540	2,348	— 7.6
Wyoming	2,515	2,905	2,993	+ 3.0	83.8	96.8	99.8	22,255	24,664	23,891	— 3.1
Total U. S.	119,446	130,407	142,678	+ 9.4	3,981.5	4,346.9	4,755.9	1,026,389	1,097,875	1,242,818	+13.2

* Texas data by districts based on A.P.I., and so do not agree exactly with state total, which is on Bureau of Mines basis.

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TO MARK PROGRESS

Anglo-American Oil Agreement Denounced By Industry's Leaders at October Meetings

Most important oil industry subject during October was the Anglo-American oil agreement. A torrent of protest rose from the industry against the treaty. A number of important oil meetings were held, and every one was featured by vigorous opposition to the provisions of the agreement.

These meetings included the annual meeting of the American Association of Oilwell Drilling Contractors, the quarterly meeting of the Interstate Oil Compact Commission, the annual meeting of the directors of the Independent Petroleum Association of America, the monthly meeting of Petroleum Industry War Council, a meeting of the East Chapter of the American Petroleum Institute.

All the meetings, except one, adopted resolutions denouncing the agreement, because "(1) it would legalize and establish the cartel business system, which would be the very opposite of the American free enterprise system; (2) it would result in government bureaucratic control of the industry, which would drive the independent oil operator from business; (3) it lacks reciprocity, since non-producing nations would be given an equal say with the United States, which produces approximately 67 percent of the world's oil, in determining production, marketing, distribution and price; (4) it seeks through the backdoor route of a Senate-ratified treaty to secure control of the oil industry, an action not permitted by the constitution through direct congressional action."

The one meeting that failed to adopt a resolution opposing the agreement was the Petroleum Industry War Council. A vigorous attack upon the agreement, precipitating a three-hour debate marked this session. But the council members voted to heed a plea by Deputy Administrator Ralph K. Davies not to do anything which would imperil the close relations existing between the Petroleum Administration for War and the government's advisors from industry. Further studies of the document will be made by PIWC.

Oil men realized that the problems of industry will be stupendous when peace comes, with enlarged foreign production likely to create an oversupply of cheap petroleum. However, there was general agreement with the thoughts of Ralph T. Zook, president of the Independent Petroleum Association of America, who said, "If it is a case of take it or leave it, then I say let's leave it, and take our chances on American initiative and enterprise enabling us to weather post-war conditions, however chaotic they may be."

The opposition of the industry reached "red hot" fever after George A. Hill, Jr., an attorney and president of Houston Oil Company of Texas, pointed out that the agreement would have the status of an international treaty should the Senate approve it. "A treaty is the supreme law of this land," warned Hill, "taking precedent over all state laws, over federal laws, and even over the Constitution of the United States." This meant that no additional legislation would be necessary to establish government control over the industry.

It was pointed out that the aims of the agreement (to allocate production quotas throughout the world, to allocate marketing quotas throughout the world, and to fix prices) could not possibly be achieved unless it is planned to establish an international OPA, which not only would regulate prices, but which also would be empowered to allocate production, processing and marketing quotas to all countries. "The United States either plans government control or representatives of our national government are guilty of placing this nation in a position where its pledges 'are meaningless and given without intent to perform,'" charged Glenn McCarthy, Houston, operator and co-chairman of the Texas Operators Committee, which was created in September to fight the agreement.

Much of the industry's concern grows out of the vagueness of the language used, which J. Howard Pew, president of Sun Oil Company, declared made the proposal "just as innocuous or as vicious as its administrators desire to make it." In this connection, the London Economist aptly described general opinion with these words: "If the art of diplomacy consists of disguising intentions, then the Anglo-American oil agreement is a masterly document. It completely defies interpretation or, rather, it offers too wide a choice of interpretation to make any interpretation possible."

The importance of the oil agreement was being held up as going far beyond the scope of petroleum itself, and the Texas Operators Committee was preparing to carry the story of its significance to all businesses, to other business men through civic clubs, etc. General opinion was that the agreement undoubtedly set the precedent upon which later accords will be reached on many other commodities, because it happens to be the first attempt to carry out that principle of the Atlantic Charter which provides all nations shall have "access, on equal terms, to the trade and to the raw materials of the world." Declaring the control of raw materials by an international commission, which would fix production, marketing and prices, would result in the establishment of the cartel business system, J. Howard Pew, denounced such plans as being the "antithesis of our American competitive system . . . and for more than 50 years it has been the American public policy to outlaw monopolies growing out of schemes for price-fixing and production control."

Universal Reduces Process Royalty Rates

Universal Oil Products Company, effective November 1, 1944, made the third reduction of royalty rates in its history. The royalty rate for UOP thermal cracking now is 3 cents instead of the previous 5 cents per barrel. In 1922, when the first UOP cracking unit was installed the royalty rate was fixed at 15 cents per barrel throughput and a yield of 21 percent of gasoline was

Crude Oil Run to Stills, Production of Refined Products, and Stocks for the Four-Week Period Ending October 28, 1944

(Figures, in thousands of barrels of 42 U. S. gallons each, based on reports of American Petroleum Institute. Production and stocks include reported totals plus estimated amounts to make these figures on a Bureau of Mines basis)

DISTRICT	Daily Refining Capacity		Crude Runs to Stills		Production				Stocks at Refineries, Terminals and in Pipe Lines				Crude Oil	
	Potential Rate	Percent Reporting	Daily Average	Percent Operating	Gasoline*	Kerosine	Gasoil and Dist. Fuel Oil	Residual Fuel Oil	Finish and Unfinished Gasoline	Kerosine	Gasoil and Dist. Fuel Oil	Residual Fuel Oil	Daily Average Production	Stocks
East Coast, Texas Gulf, Louisiana Gulf, North Louisiana-Arkansas, and Inland Texas (Combined at request of PAW)	2,518	90.3	2,375	94.3	28,860	3,635	12,024	16,783	36,524	9,987	26,811	21,816	.....	.....
Appalachian District 1	130	83.9	102	78.0	1,196	252	335	375	2,330	319	511	324	.....	.....
Appalachian District 2	47	87.2	56	118.6	702	45	148	352	1,321	46	191	137	.....	.....
Indiana, Illinois, Kentucky	824	85.2	763	92.4	10,045	870	2,708	4,415	16,503	2,637	7,023	3,991	.....	.....
Oklahoma, Kansas, Missouri	418	80.2	373	86.8	5,533	475	1,458	1,856	6,896	778	2,334	1,650	.....	.....
Rocky Mountain District 1	13	17.0	12	90.4	147	12	30	124	61	10	14	29	.....	.....
Rocky Mountain District 2	141	58.3	99	70.5	1,360	60	305	664	1,444	98	387	590	.....	.....
California	817	89.9	823	100.8	8,527	144	2,848	10,808	13,979	448	11,502	35,687	.....	.....
Total U. S. October 28, 1944	4,908	87.2	4,603	93.8	57,370	5,453	19,856	35,377	79,058	14,323	48,863	64,224	4,740	221,711†
Total U. S. September 30, 1944	4,908	87.2	4,775	97.3	.....	.....	.....	.....	78,028	14,583	45,320	64,226	.....	222,393‡
Total U. S. October 30, 1943	.....	.....	4,184	.....	.....	.....	.....	.....	69,092	11,229	44,713	63,785	.....	247,219‡

* Includes natural gasoline blended at refineries. † Bureau of Mines, October 21, 1944. ‡ Bureau of Mines, September 30, 1944, and October 30, 1943.

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guaranteed. By 1924, despite increases in yield and quality of products, the royalty was lowered to 10 cents per barrel. Again in 1938, the process was still further improved, and the royalty was cut to 5 cents per barrel. From 1922 to 1944 the yield of gasoline has been increased from 21 percent to over 60 percent on a comparable charging stock, services to licensees have expanded, and the royalty rate reduced 80 percent.

Synthetic Fuel Plant Planned Near Pittsburgh

Plans for construction of a research and development laboratory by the Bureau of Mines at Bruceton, Pennsylvania, south of Pittsburgh, to carry on the program for demonstrating commercial possibilities of producing fuels from coal and oil shale were announced by Secretary of the Interior Harold L. Ickes October 25.

Ickes said that buildings comprising the large laboratory, to be the most modern of its type in the world, should be ready for occupancy in a year.

The laboratory, consisting of three large three-story buildings, a power house and several smaller service buildings on seven acres of land, will not engage in the demonstration of methods for commercial production of synthetic fuels but will work out the "kinks" in the various processes which are to be studied.

B. C. Voshell Heads National Lubricating Grease Institute

B. C. Voshell, Socony-Vacuum Oil Company, New York, was elected president of National Lubricating Grease Institute at a meeting at Chicago October 25. He had been vice president, and is succeeded in that position by C. W. Georgi, Enterprise Oil Company, Buffalo. G. W. Miller, Battenfeld Grease & Oil Company, North Tonawanda, New York, and E. V. Moncrieff, Swan-Finch Oil Company, New York, were reelected secretary and treasurer, respectively. The institute's board of directors was increased from 12 to 18, and 11 new directors were elected.

Robinson Named President American Gas Association

J. French Robinson was elected president of the American Gas Association at the annual business meeting in New York. No general meeting was held by the association because of travel conditions.

Robinson became president of East Ohio Gas Company, Cleveland, four years ago, previously having been president of Peoples Natural Gas Company, Pittsburgh, both companies being units of Consolidated Natural Gas Company. During the war he has been a member of PIWC, and chairman of the natural gas and natural gasoline committee of PAW, and has served on several committees of WPB.

Consulting Chemists Elect Albert P. Sachs President

Albert P. Sachs of New York was elected president of the Association of Consulting Chemists and Chemical Engineers at the annual meeting in New York on October 24. Other officers include Henry M. Shields, partner of Bull and Roberts, New York, vice president; Claude P. Davis, Schwarz Lab-

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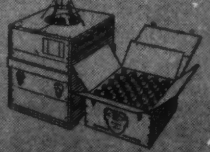

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oratories, New York, secretary, and Sam Tour, New York, treasurer.

The meeting was held in the form of a symposium on liquid fuels, with Benjamin T. Brooks, Walter M. Fuchs and Henry M. Shields as speakers, the discussion being led by Sachs.

PAW Refining Directors Named in Districts 1 and 4

Carleton J. Everett, domestic product coordinator for Standard Oil Company of New Jersey in New York prior to joining PAW in June, 1943, as a refining analyst, has been named director of refining for District 1. He has been acting director since the resignation last June of William Naden.

Edward A. Markey, formerly with Continental Oil Company, who joined PAW in June, 1943, as a member of the facility and security staff of District 4 and the following August succeeded Robert N. Sears as assistant director of refining, has been named director of refining for District 4.

Duller Assistant Chief Engineer for Continental

T. O. Duller has been appointed assistant to M. E. Clawson, chief engineer for Continental Oil Company at Ponca City. Duller joined the company at Fort Worth in 1925 as a draftsman, transferred to the engineering department at Ponca City in 1928, and was made chief designer in September, 1942.

Harris Heads Arkansas Natural Gas Company

D. W. Harris has been elected president of Arkansas Natural Gas Company with headquarters at Shreveport. He has been its vice president and general manager since 1928. Its subsidiary companies are Arkansas Fuel Oil Company, Arkansas-Louisiana Gas Company and Arkansas Pipeline Company.

Harris has held several executive positions with Cities Service Company and its subsidiaries in Denver, Bartlesville and New York. He is a member of the American Gas Association.

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Robert E. Wilson and A. W. Peake Head Standard Oil Company (Indiana)

Robert E. Wilson, president of Pan American Petroleum and Transport Company, is to become chairman of the board and chief executive officer of Standard Oil Company (Indiana) upon retirement January 1 of E. G. Seubert as president of the company. Seubert will remain as a director, and become chairman of the executive committee. A. W. Peake will advance from vice president to president of Standard Oil Company (Indiana), and will be replaced as vice president by F. O. Prior, now president of Stanolind Oil & Gas Company. Prior will also be chairman of the board of Stanolind Oil & Gas Company, Stanolind Pipe Line Company and Stanolind Oil Purchasing Company, as Peake has been. E. F. Bullard, executive vice president, will become president of Stanolind Oil & Gas Company. Wilson also succeeds Seubert as chairman of the board of Pan American Petroleum and Transport Company.

The reorganization is designed to relieve Seubert of the greater part of his executive responsibilities and retain the advantages of his long experience, an announcement said. He has been with the company 52 years, and has been its president 15 years. Starting in 1891 as a clerk, after 20 years he became auditor, advanced to director, secretary and treasurer in 1919, became vice president in 1920, president in 1927, and chief executive officer in 1929.

DR. ROBERT E. WILSON

A. W. PEAKE

Falls, Pennsylvania, and was graduated by the College of Wooster with magna cum laude in 1914 and Ph.B., and received the degree of Sc.D. from that institution in 1931. He received the degree of B.S. from Massachusetts Institute of Technology in 1916, following two years of advanced work in chemical engineering and service as research associate in applied chemistry. After service in the Army's chemical warfare division as captain and major, he returned to MIT in

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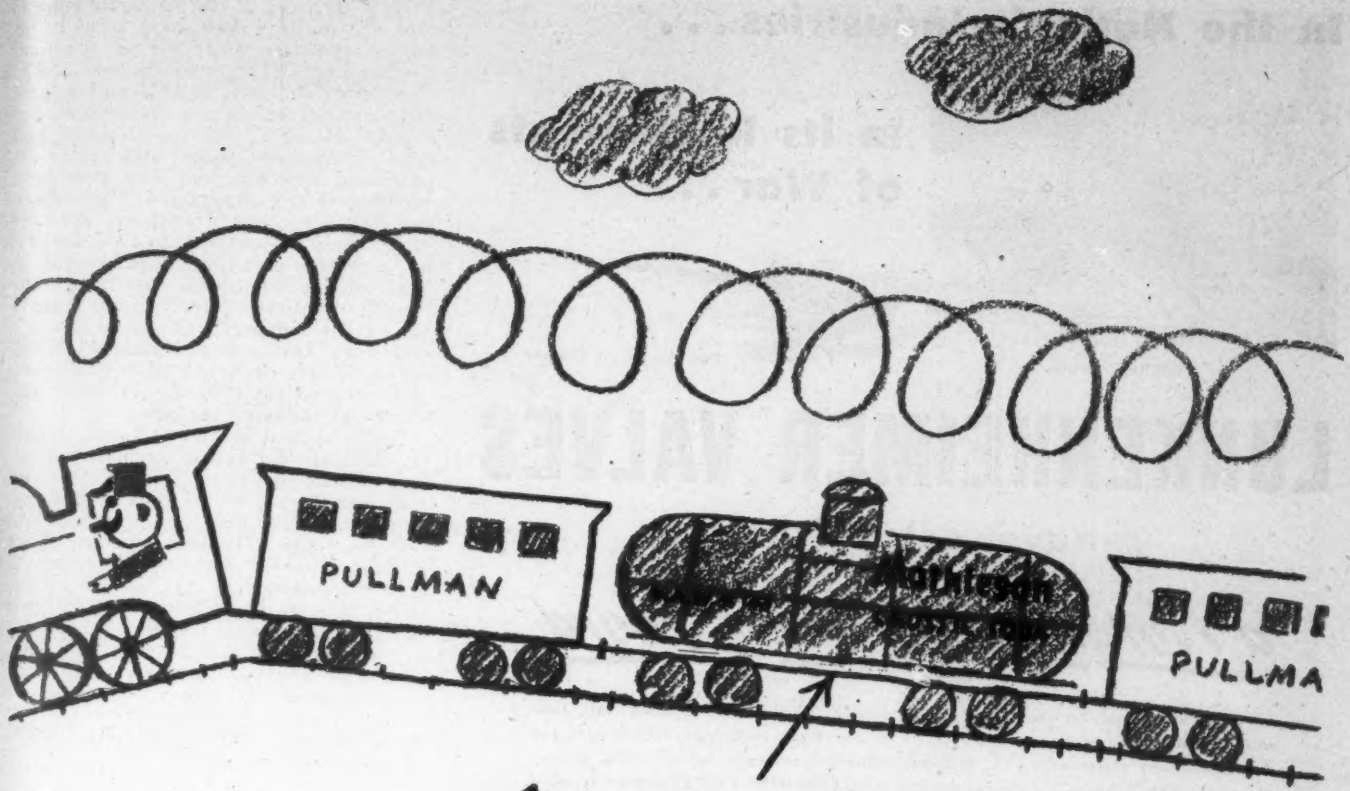

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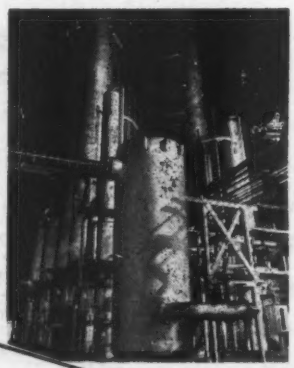

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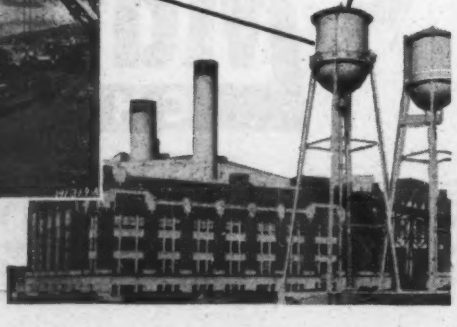


High Pressure Steam and Power

1919 as director of the research laboratory of applied chemistry, later being named associate professor of chemical engineering. He joined Standard Oil Company (Indiana) in 1922 as assistant director of research, and successively became assistant to the vice president and head of the development and patent department, director, and vice president. He became vice chairman of Pan American Petroleum and Transport Company in 1935, and its president in 1937. In 1940 he accepted part-time appointment as head of the petroleum section of the council of national defense. He is a member of the American Chemical Society, American Institute of Chemical Engineers, Society of Automotive Engineers, and others. In 1939 he received the Chemical Industry Medal.

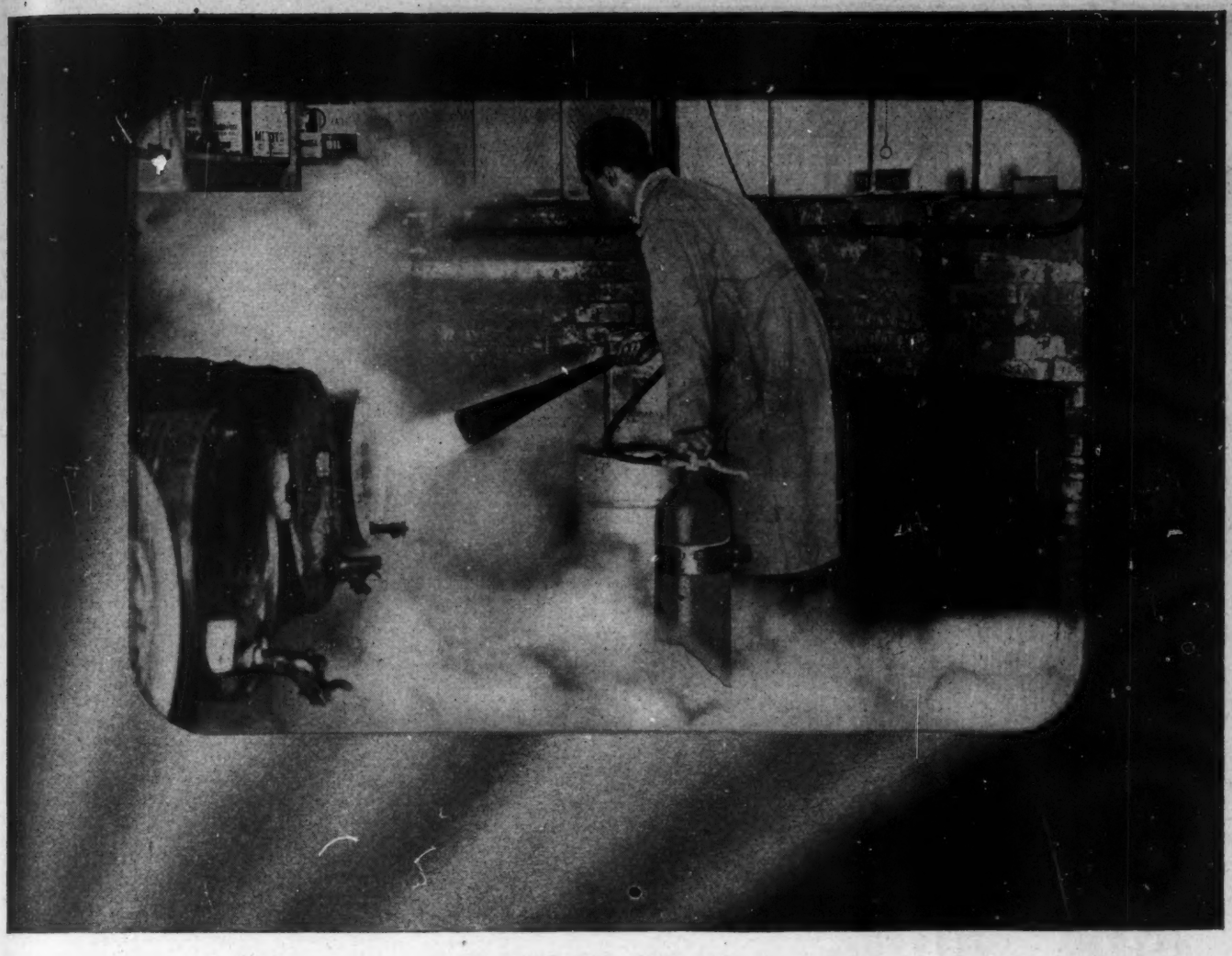
Peake started in the petroleum industry in California as a roustabout, following graduation from Leland Stanford University's school of mining and geology. He has been with the Standard Oil Company (Indiana) group since joining Midwest Refining Company as field superintendent at Casper, Wyoming, in 1916. In 1928 he went to Dixie Oil Company at Shreveport, Louisiana, as vice president and director, and later president. In 1930 he went to Chicago as vice president and director of the crude-oil-production department, and, as such, executive of the Stanolind group of companies.

Hughes Research Chief For Standard of Ohio

Dr. Everett C. Hughes has been appointed chief of the research division of the manufacturing department of The Standard Oil Company (Ohio), succeeding Dr. R. E. Burk, who has accepted a position with E. I. duPont de Nemours Company

Dr. Hughes received his B.A. from Carleton College in 1927 and his Ph.D. from Cornell University, where he was research assistant in chemistry and physics from 1928 to 1930. He has been associated with the company since 1930. He was chairman-elect of the Cleve-

DR. E. C. HUGHES



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land branch of the American Chemical Society in 1939 and counselor of the same organization from 1939 to 1942.

He has been active during the war on a subcommittee to the technical advisory committee of the Petroleum Industry War Council.

Dr. Hughes has been granted numerous patents on sweetening of gasoline, catalytic reforming, lube oil additives, and manufacture of paper cans.

Dr. Burke, who in addition to his work with Standard Oil Company (Ohio), has been professor of chemistry at Western Reserve University; has been named special asistant to the plastics chemical director at E. I. du Pont de Nemours and Company. He is chairman of the committee on catalysis of the National Research Council, and vice chairman of the Division of Petroleum Chemistry of the American Chemical Society.

Danner and Cragin Join Houdry Process Corporation

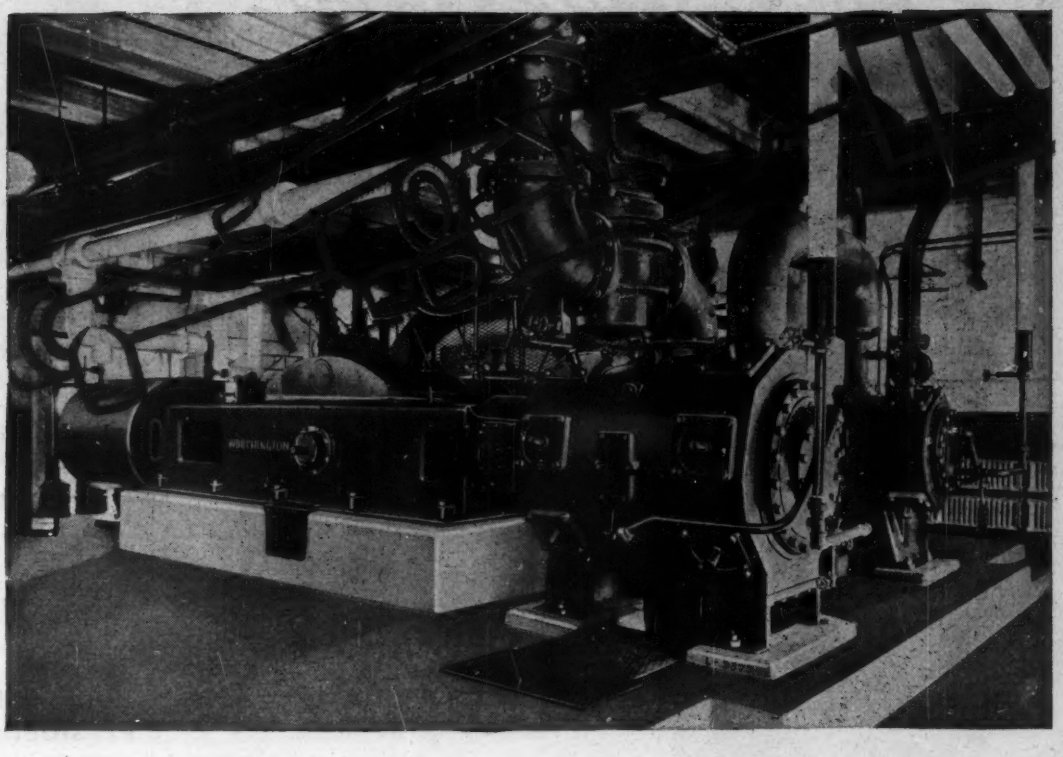
Arthur V. Danner and Robert B. Cragin havs been elected vice presidents and members of the board of directors of Houdry Process Corporation, Wilmington, Delaware. Danner also was made a member of the executive committee. Cragin will be in charge of sales engineering and serve as technical advisor.

Danner has for seven years been a patent attorney for Socony-Vacuum Oil Company and since the war has been on loan to the Petroleum Administration for War where he served as chief of the process section of the refining division. His previous experience was in the chemical industry and as an examiner in the patent office. He has a degree in law from New York University, and a bachelor's degree in chemistry obtained by studies started at University of Indiana and completed at George Washington University.

Cragin has been director of petroleum research for The M. W. Kellogg Company, and later sales engineer. For the past three years he has been assistant

ARTHUR V. DANNER

WHEN TO OMIT INTERCOOLERS?



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ROBERT B. CRAGIN

director of the refining division of PAW, where he was closely associated with the aviation-gasoline program. He is a chemistry graduate from Princeton University.

Bedford Executive Vice President of Jersey Company

A. Clarke Bedford has been elected executive vice president of Standard Oil Company of New Jersey. As vice president he has been in charge of sales of the company for the past two years.

Bedford began his business career with the company in 1913, following graduation from Williams College. His experience has been in refining and production as well as selling. During the first world war he served as a captain.

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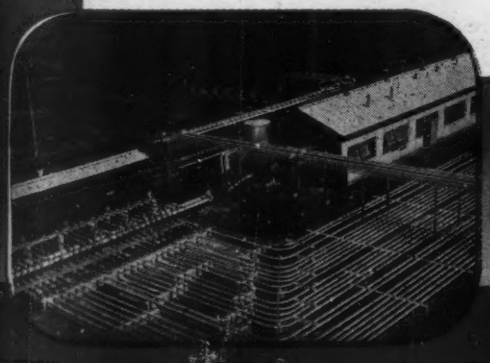

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Directors to Consider API Annual Meeting

One of the questions to be considered by directors of the American Petroleum Institute in Washington December 7 will be the possibilities and dates for the deferred 1944 annual meeting, which was designated the silver anniversary meeting.

The meeting of directors will be held following a session of the Petroleum Industry War Council, also in Washington.

When the annual meeting was postponed in September, having been set for November, there were expressions that it might be held in the spring of next year.

California Association Meet Reviews Natural Gasoline

C. E. Webber, chief of the natural-gasoline section of Petroleum Administration for War, speaking before the California Natural Gasoline Association at Los Angeles on October 13, reviewed growth of the industry in that state and pointed to further increases needed and contemplated.

California production of natural gasoline and allied products has been increased to 52,000 barrels daily from the prewar figure of 41,000 barrels, Webber pointed out. This increase, however, will not meet the accelerated demand of the Pacific war. Throughout the country, the natural-gasoline industry is spending $30,000,000 on building or expanding 30 major plants.

The technical program included: "Catalytic Processes Utilizing Paraffinic Hydrocarbons," by Dr. H. H. Wenzeke, Universal Oil Products Company, Chicago; "Butane Dehydration by the Houdry Process," by R. C. Lassiat, Catalytic Development Corporation, and F. D. Parker, Bechtel-McCone Corporation; "A Rapid Test for Isobutane (+) Fractions in Gasses," by W. M. Schaufelberger and G. M. Liljenstein, California Research Corporation, and "Detection of Reservoir Gas Movement in Pressure Control," by H. Van Wingen and E. P. Valby, Richfield Oil Corporation.

Davies and Ickes Block Action by PIWC in Opposing Oil Agreement

Attack upon the Anglo-American oil agreement marked the October session of the Petroleum Industry War Council, paving the way for further studies of the document by the national oil policy committee with a view to making "constructive suggestions" for its clarification and improvement.

The discussion was touched off by a resolution condemning the agreement introduced by George A. Hill, Jr., of Houston Oil Company and supported by Ralph T. Zook, president of the Independent Petroleum Association of America and other minority members of the national oil policy committee, following three days of consideration of the matter prior to the meeting. But the council heeded a plea by Deputy Administrator Ralph K. Davies not to do anything which would imperil the close relations existing between the government and the industry.

During the committee's meetings, both Davies and Charles Rayner, petroleum adviser to the State Department, met with the oil men in an effort to head off anything which might lead to a split between the council and PAW.

From one source came a story, denied in all official quarters, that members of the committee had conferred with Administrator Harold L. Ickes on the projected resolution in a stormy session in which the administrator was said to have challenged the council's authority to go into postwar matters and threatened to dissolve the organization if the resolution was brought up.

A way out of the situation was opened by Ickes in a letter to PIWC Chairman William R. Boyd, in which he said "I

Speakers Luncheon in Connection with Nineteenth Annual Meeting of California Natural Gasoline Association, Biltmore Hotel, Los Angeles, October 13, 1944: Outside of table, left to right: Harry Ransford, Signal Oil Company; Richard Sneddon, Petroleum World; J. E. Sherborne, Union Oil Company; W. C. Dayhuff, California Research Corporation; H. R. Linhoff, Richfield Oil Corporation; G. M. Liljenstein, California Research Corporation; E. P. Valby, Richfield Oil Corporation; Wm. F. Lowe, Natural Gasoline Association of America; R. R. Crippen, The Texas Company; W. W. Robinson, Jr., The Texas Company; R. C. Lassiat, Catalytic Development Corporation; P. S. Magruder, General Petroleum Corporation; Geo. L. Tyler, California Natural Gasoline Association; R. D. Gibbs, Union Oil Company; Chas. E. Webber, Petroleum Administration for War; C. D. Gard, Union Oil Company; R. E. Miller, Hanlon-Buchanan, Inc., M. L. Arnold, Richfield Oil Corporation; R. W. Heath, Signal Oil & Gas Company; Chas. L. Thomas, Universal Oil Products Company; R. E. Beckley, Standard Oil Company; Kenyon L. Reynolds, Petroleum Administration for War; F. D. Parker, Bechtel-McCone Corporation; G. C. McLaren, Standard Oil Company; W. M. Schaufelberger, California Research Corporation; S. F. Magor, Superior Oil Company; J. H. Kunkel, Petroleum Engineer; Walter Monroe, California Oil World; A. K. Hegeman, Clark Bros. Company; P. E. Fluor, Fluor Corporation. Inside of table, left to right, around: R. W. Garman, Petroleum Administration for War; Clyde Peter, Belridge Oil Company; C. L. Hutchings, Tide Water Associated Oil Company; Randal Maass, General Petroleum Corporation; R. E. Foss, Barnsdall Oil Company; I. B. Funk; J. A. Campbell, J. A. Campbell Company; J. B. Taylor, Signal Oil & Gas Company; H. M. Paulsen, Norwalk Company; D. M. Wolfe, Standard Oil Company; W. L. Rifenberick, Industrial Engineers, Inc.; W. A. Kirk, California Southern Oil Company; H. W. Parmelee, Del Valle Gasoline Company; H. P. Saueressig, Southern California Gas Company; H. A. Dresser, Fluor Corporation; H. E. Moulton, Cansler-Canfield-Midway Oil Company; J. S. Fluor, Fluor Corporation; M. L. Fort, Pacific Lighting Corporation; R. S. Tulin, Shell Oil Company; F. J. Colton, Tide Water Associated Oil Company.

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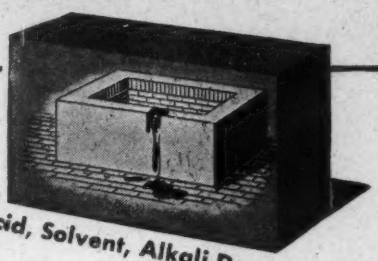

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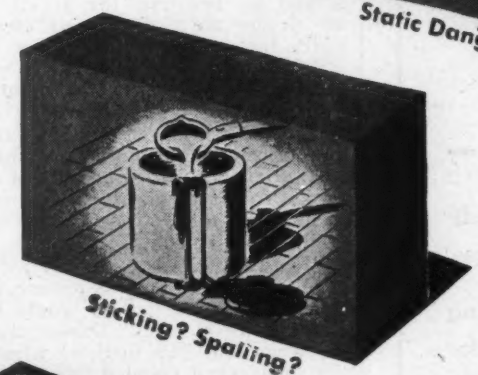
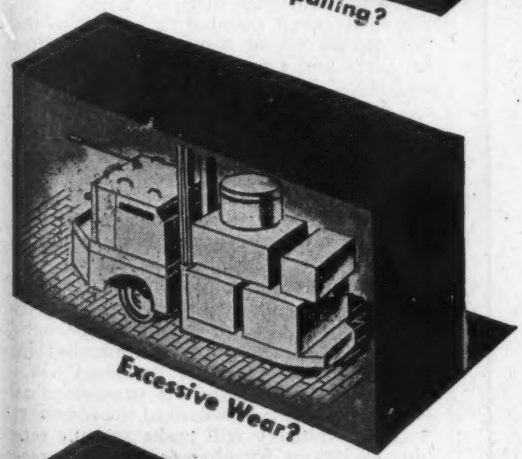


Sticking? Spalling?



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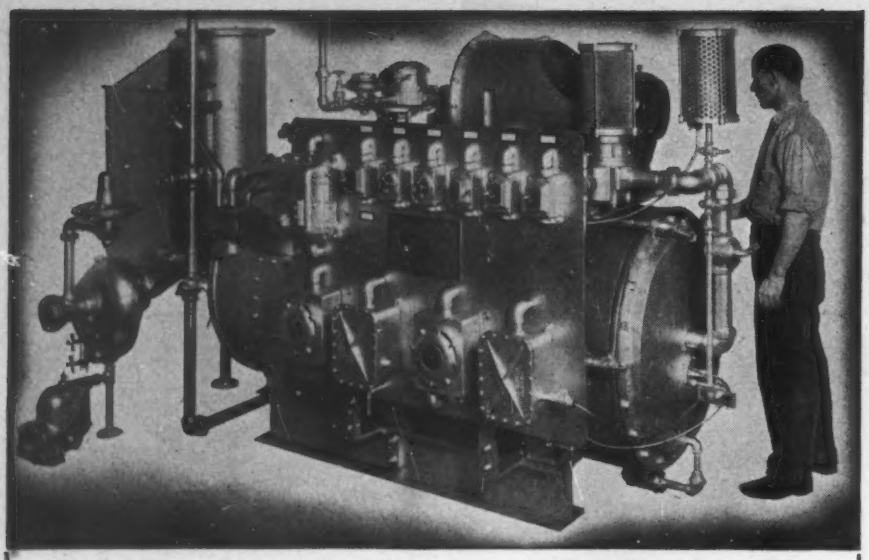

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understand that the PIWC and certain of its committees desire to register objection to the recently negotiated Anglo-American oil agreement.

"If the Council or any of its committees do so desire to record with me such views on the subject, I request that when they make known their objections, they likewise make known in specific language exactly how, in their view, the existing document might be revised so as to remove the points of objection cited. This would be in the interest of the creative and helpful approach, as opposed to a purely destructive one."

While a majority of the committee were receptive to this approach, several members sought an immediate showdown, and took their resolution into the meeting, where J. Howard Pew, president of Sun Oil Company, and others delivered attacks on the agreement. The resolution was defeated by a vote of 22 to 11, but with the definite understanding that the action was not to be construed as favoring the treaty nor as restricting the right of any member to carry the matter to the Senate Foreign Relations Committee, which is planning to hold hearings on it next month.

Because of conflicting stories circulating in Washington, Davies, after the council meeting, pointed out that when the agreement was in process of negotiation, PAW officials made arrangements to defer its application until the industry could make its views known.

"Not knowing what form it would take, we put in that assurance that the industry and the public would have an opportunity to react," Davies said. "And we went one step further; when President Roosevelt decided to send it to the Senate, we hoped for Senate committee hearings and I went to Senator Maloney and told him we would request that he call industry representatives.

"All the way through, there has been a disposition to follow the recommendations of oil industry interests and to get their reaction. What we are trying to do is to get that industry expression in some coherent form and in some constructive form."

The deputy administrator suggested that no matter how the agreement was written, its language would be susceptible of differing interpretations, but he emphasized that neither he nor PAW's legal staff had viewed its provisions as setting up federal control of the industry.

If the industry will make specific recommendations for changes in the agreement with which PAW can go along, he promised, they will be taken up with the State Department.

Davies denied that Ickes had threatened to dissolve the council if it went through with a resolution of the agreement, explaining that he had talked with the committee during its deliberations, urging that it develop recommendations for changes to go with any report it made on the pact.

At the same time, he said, he pointed to the cordial relations which have existed between PAW and PIWC and argued that any condemnation of the agreement at this particular time, at the height of the political campaign, could be interpreted by Ickes only as a personal affront, in the face of which, while there still would be a council, its relations with the administrator could not help but suffer.

Ickes himself, Davies said, never entered into the picture beyond sending

his letter urging that constructive suggestions be submitted. The administrator did not meet with the committee and did not talk with any members until he went into the conference room to address the council.

Pew's attack on the agreement was based on the charge that its language is so "vague and ambiguous" that it is without positive meaning or, alternatively, a blank check "which would give to the federal government unlimited and unspecified powers of the greatest scope over every activity of our industry."

His own conclusion, he told the council, was that "this is a deliberate attempt to place the American petroleum industry under the bureaucratic control of the federal government," which could be achieved only through embroiling the domestic oil industry in a vicious cartel system, halting its progress and detrimental to the welfare of all.

"Despite vague, ambiguous and double-talking terms, it is clear to anyone who can read the English language that the commission, which the agreement creates, would have authority to propose undertakings for the control of prices and the allocation of production and marketing quotas," he asserted. "This agreement sets forth objectives which can be achieved only through production control, or control of marketing, or control of prices, or all of these, and I challenge anyone to dispute this assertion."

Cartelized or Free

Pointing out that for more than 30 years the industry has grown great by shunning all cartel practices and by engaging in spirited competition, Pew warned that the country cannot be cartelized in its foreign trade and free in its domestic enterprise, and "once we start to regiment through allocations, price fixing and production controls, our activities in the foreign field, we of necessity will have forced upon us by the government restrictive measures upon operations that fall wholly within the domestic field."

There can be no distinction between so-called "private" cartels and cartels under government control, he contended.

Some attention should be given, Pew suggested, to the question where the agreement originated and why. It did not originate in the industry, which has expressed opposition to it, he said; it did not originate in Congress, which has often gone on record as opposed to cartel and monopoly agreements, and the Department of Justice has disavowed responsibility.

Whether it originated in the Department of State is not clear, he said, but "at all events, we do have a right to know where this scheme originated and the purposes for which it was formulated. Likewise we have a right to know what relationship, if any, exists between the Anglo-American petroleum agreement and the Bretton Woods monetary agreement, the Dumbarton Oaks understanding and the dozen and one other commodity agreements which are in the process of being negotiated on the pretext of promoting foreign trade in the postwar years.

"The oil cartel agreement is the first of a long series of similar cartels which the economic planners are preparing to ram down the throats of the American people. Because oil is the first of these agreements, and because we have had the opportunity of familiarizing ourselves with all of its implications, it becomes our solemn duty, as American

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citizens, to state our objections clearly and fully so that the Senate of the United States, as well as the American people, shall have a full understanding as to what is comprehended."

Much has been said, Pew concluded, to the effect that whether we like it or not, other nations are so wedded to the cartel system that we must accept that method of doing business in the foreign field.

"We do not have to do anything of the sort," he declared. "So great will be our economic strength after this war that the United States will not have to submit in foreign trade to the dictatorship of any nation. No international cartel arrangement can be made fully effective without the participation and the cooperation of this country and its nationals.

"Instead of supinely capitulating to the reactionary, backward cartel system, our government should exert leadership for the elimination of cartels and demand that American business should be free—free to engage in world trade without being forced to submit to cartel restrictions."

Petroleum Economics

The monthly report of the committee on petroleum economics was confined to a resume of five studies which have been made on the probable postwar demand for petroleum. The committee developed no conclusions, but contented itself with tabulating the estimates of the several writers.

At the pre-council meeting of the committee on production, John R. McWilliams, PAW director of production, submitting his first report, pointed out that outstanding features of the situation are that crude oil production is at an all-time high, the trend of the crude-oil stocks curve, which has been generally downward for some time, appears to have been arrested.

McWilliams also reported the result of revision of estimates of maximum efficient rates of crude oil production based on development of recently discovered important new reserves.

He reported that the revised estimates place the maximum efficient rate for the United States at 4,620,000 barrels daily for the current quarter, 4,610,000 barrels for the first quarter of 1945, 4,600,000 barrels for the second quarter, 4,585,000 barrels for the third quarter and 4,570,000 barrels for the fourth quarter, these figures being approximately 85,000 barrels daily higher than the previous calculations, but to be considered only as preliminary pending the completion of a field-by-field survey now being conducted.

Large Refinery Projects Planned With War Ending

Relaxation of restrictions on materials as victory progresses will embark the oil industry of the United States on a program of refinery construction at home and abroad expected to cost $352,000,000, it has been disclosed by a survey conducted by Petroleum Administration for War. Plans revealed call for spending $176,789,385 on domestic plants and $176,155,000 on foreign construction, not including rebuilding or rehabilitation of facilities in areas occupied by the enemy.

PAW urged that the War Production Board give immediate authorization for the proposed construction which includes five new refineries abroad, $146,-

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1. Priming Coat of Armstrong's Asphaltic Paint seals the walls of the cold room before insulation is erected.

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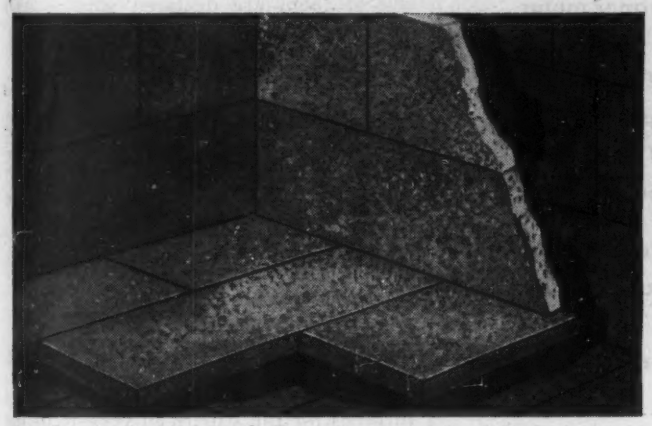
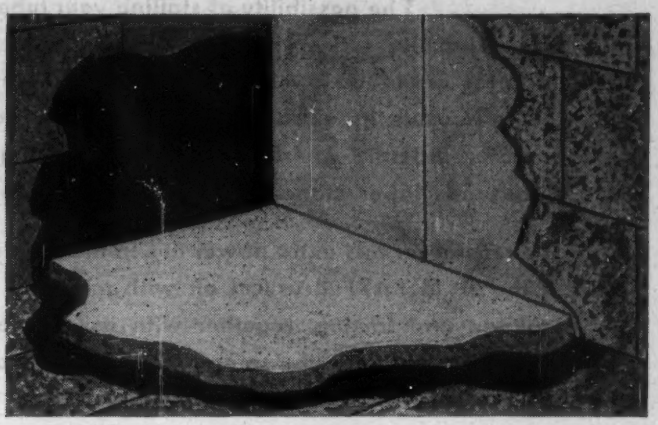


3. Inner Layers of Armstrong's Corkboard keep heat out of room with maximum insulating efficiency.



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FOR COMPLETE INFORMATION about this construction—including engineering drawings and erection specifications—write to Armstrong Cork Co., Building Materials Div., 7511 Concord St., Lancaster, Pa.

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000,000; and additional facilities $30,155,000. Domestic projects listed are: Catalytic cracking, $90,775,000; lubes, $42,869,928; greases, $3,524,170; waxes, $2,627,000; crude topping, thermal cracking and coking, $10,612,875; solvents and specialties, $2,075,000; alkylation, isomerization and polymerization, $7,348,000; asphalt, $1,765,000; sulfuric acid, $1,570,000; treating, $500,000; utilities, services, etc., $9,272,412; research and development, $3,850,000.

Government Catalogs Plants To Be Leased or Sold

Defense Plant Corporation in preparation for postwar disposal of plants and facilities financed by Reconstruction Finance Corporation, has issued a 150-page catalog of plants and sites to be sold. Included are 60 oil-refining and synthetic-rubber plants, three pipe lines, and a number of grain-alcohol plants. It was announced that negotiations for purchase or lease of the properties will be entered into, subject to contingencies of present contracts and the time the plants will continue in war use.

Secretary of Commerce Jesse H. Jones explained that issue of the catalog at this time is to give those interested advance information as to size, character and location of plants so that when any of them are declared surplus and no longer needed in the war effort, they can be converted to civilian production with all possible speed.

In the case of oil-refining plants, the listings indicate that in the majority of instances the facilities to be disposed of are additions to existing plants for the manufacture of aviation gasoline, and as such would be of value only to those now operating them.

Jet Planes Use Either Gasoline or Kerosine Fuel

Jet plane turbines operate satisfactorily with either kerosine or gasoline, according to the General Electric Company engineers who are making the gas turbines for the American version of the revolutionary-type aircraft that has been used by the British against German robot bombs. These propellerless craft can take off almost from scratch without a warm-up period, and is described as a single-seater, high-altitude fighter.

When the jet plane is in flight," a release by the company states, "no visible flames come out of the exhaust. And because continuous ignition is not required, radio interference and high-altitude ignition problems are eliminated.

"The turbine is a compact, self-contained unit which has only one moving part. Air is taken into the turbine, compressed, and passed into chambers where its temperature is increased by the combustion of fuel, creating hot gases which are discharged through a tailpipe nozzle.

"Forward thrust of the plane is developed as the reaction to this high-velocity discharge in accordance with the physical law that for every action there is an equal and opposite reaction. A common example of this principle is the rotary lawn sprinkler, which is rotated in one direction by jets of water directed in the opposite direction.

"Because this thrust power is produced directly without requiring gearing or a propeller, vibration is minimized, and reduced weight per horsepower is made possible."

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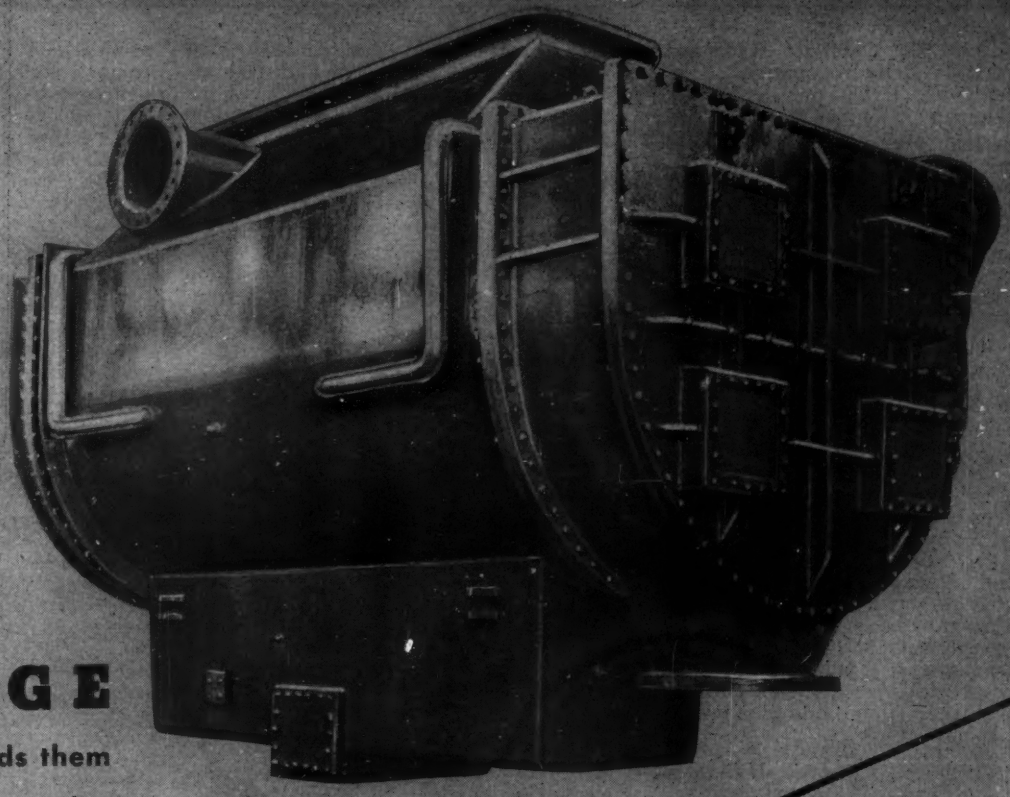

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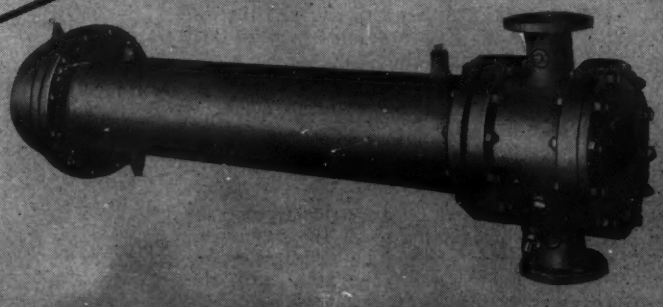

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GRAHAM MANUFACTURING CO. INC.

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DIGEST OF UNITED STATES PATENTS

On Hydrogenation and Halogenation

Compiled by HEINZ HEINEMANN

U.S.P. 2,321,551. Catalytic Hydrogenation and Dehydrogenation. D. J. Loder to E. I. DuPont de Nemours & Company.

A method is employed which involves subjecting benzol and cyclohexanol or cyclohexanone or both to a catalytic hydrogenation step, separating phenol and cyclohexane from the resulting product (by distillation), producing cyclohexanol or cyclohexanone or both by oxidation of the cyclohexane and recycling the cyclohexanol to the first step.

U.S.P. 2,321,841. Refining Hydrocarbons. V. Mekler and J. H. Curtis to The Lumnus Company.

Heavy hydrocarbons are cracked to effect viscosity breaking and immediately thereafter subjected to non-destructive hydrogenation in the presence of hydrogenation catalysts, so that the heavy unsaturated products of the cracking reaction are converted into saturated products and their polymerization to tar-like products is substantially prevented. The hydrocarbons are then fractionated to obtain an additional cracking stock for conversion into gasoline and a fraction boiling within the gasoline boiling range.

U.S.P. 2,322,095. Catalytic Hydrogenation of Organic Compounds O. Schmidt to General Aniline & Film Corporation.

Hydrogenation catalysts consisting essentially of a metal selected from the group consisting of copper, cobalt and nickel, and a small quantity of at least one oxygen-containing compound of the metals of the first to seventh group of the periodic table are used at a pressure of above 50 atmospheres and at 120-300° C.

U.S.P. 2,325,072. Process for the Catalytic Destructive Hydrogenation of Heavy Oils or Residues Containing Asphalt. M. Pier and E. Donath to Standard Catalytic Company.

A process for the catalytic destructive hydrogenation of heavy oils or residues containing asphalts for the production of middle oils is described, which comprises treating the initial material with hydrogen, at a temperature between 450 and 550° C., in the presence of a hydrogenation catalyst, the activity of which lies below that of catalysts of standard hydrogenating activity, with a through-put between 0.5-1.8 kg. of initial material per liter of reaction space per hour, and at a hydrogen pressure which ranges between a pressure determined in accordance with the propane-asphalt content of the initial material so that the hydrogen pressure is 320, 360, 450, 550 and 600 atmospheres for about 8, 15, 33, 50 and 60 percent of propane-asphalt, respectively, and a pressure determined in accordance with the amount of vacuum residue of the initial material remaining after distillation at about 20 mm of mercury up to about 325° C. of about 320, 360, 450, 550 and 600 atmospheres with a vacuum residue amounting to about 10, 15, 25, 35 and 40 percent respectively.

U.S.P. 2,326,275. Process for the Preparation of Catalysts for Hydrogenation. J. Zeltner to Alien Property Custodian.

It is well known that hydrogenation catalysts can be prepared by decomposing an alloy of certain metals by the action of neutral or alkaline substances attacking only one of the alloyed metals. The present invention describes the preparation of superior catalysts and particularly of nickel catalysts by treating for instance an alloy of nickel and a more electropositive element such as magnesium or calcium with a weak or dilute organic acid, the acid being used in such proportions as to correspond to all the electropositive metals contained in the alloy. A 20 percent solution of acetic acid in water is suitable.

U.S.P. 2,328,140. Catalyst Resulting from Hydrolysis of Alloys of Catalytic Metals and Hydrolyzable Metals. J. H. Hahn to Monsanto Chemical Company.

Hydrogenation catalysts are prepared by hydrolyzing an alloy, e. g. an alloy of one part nickel and two parts aluminum, in powdered or granular form, by boiling with water. The hydrolyzed material is separated by filtration and washed. The catalyst thus prepared is used directly or may be stored for future use in the form of a wet paste or suspension in water. Such catalysts loose their activity on aging. More active catalysts, which are not subject to deterioration due to aging, are prepared by conducting the hydrolysis under controlled conditions in the presence of an organic liquid, preferably the liquid to be hydrogenated.

U.S.P. 2,328,828. Hydrogen Purification Process. R. F. Marschner to Standard Oil Company (Indiana).

Hydrogen contained in hydrogenous gas mixtures with hydrocarbons is purified by hydrogenating an aromatic hydrocarbon with the gas mixture in the presence of a hydrogenating catalyst, separating hydroaromatic hydrocarbons and subjecting the hydroaromatic hydrocarbons to dehydrogenation in a catalytic zone. The aromatics and the hydrogen are separated and the former recycled.

U.S.P. 2,329,795. Manufacture of Halogenated Hydrocarbons. H. M. Stanley and R. B. Philip to The Distillers Company.

Acetylene and/or its homologues are caused to react at an elevated temperature in the presence of a catalyst with an amount of hydrogen halide insufficient to combine with all the acetylenic hydrocarbons present and the products of reaction are brought into contact with a further quantity of the hydrogen halide in one or more separate and successive operations. Acetylene can be reacted with hydrogen chloride at 100-140° C. over metal halides, particularly mercuric chloride on porous carriers.

U.S.P. 2,329,934. Catalytic Process. F. F. Nord to Baker & Company.

Hydrogenation reactions are carried out in the presence of a catalyst comprising a colloidal solution of a metal of the platinum group and a homogenous non-resinous synthetic organic polymer which acts as a protective coloid for the metal.

U.S.P. 2,330,098. Hydrogenating Catalyst. R. Watts to Standard Oil Company of California.

An adsorptive acid-treated clay is treated with a dilute solution of hydrogen fluoride. The product is then dried at 220 to 320° F. The clay is impregnated with a molybdenum or tungsten solution, for instance by digesting tungsten trioxide in an ammonium sulfide solution, the amount of sulfide present being insufficient to completely convert the trioxide into ammonium thiotungstate. The solubility of the resulting product is much higher than pure ammonium thiotungstate. The impregnated product should contain 1-10 percent of tungsten. It is then granulated and molded into pellets by pilling or extrusion.

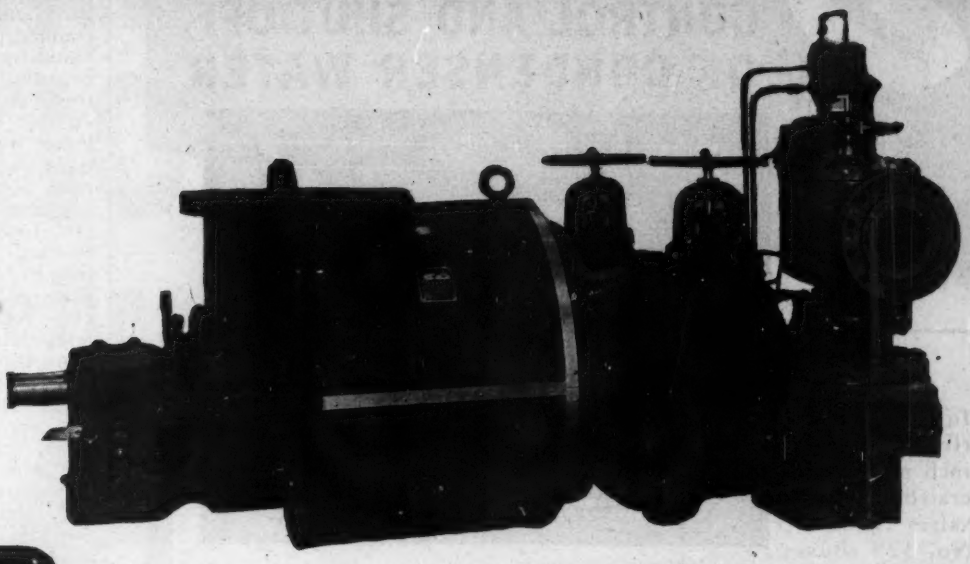
U.S.P. 2,330,174. Hydrogenation Catalyst Reactivation. K. H. Hachmuth to Phillips Petroleum Company.

Deactivated nickel-containing catalysts are treated with an aqeuous solution of nickel nitrate for such a period that between about 5 and 20 percent as much nickel, as nickel nitrate, as is contained on the body of the catalyst being treated, is absorbed on or by the deactivated catalyst. If other activate materials are incorporated with nickel in the catalyst, such as copper and/or aluminum, nitrates of such metals are incorporated in the reactivating solution. The material is dried, heated to 600-750° F. to decompose the nitrates and reduced in the presence of free hydrogen.

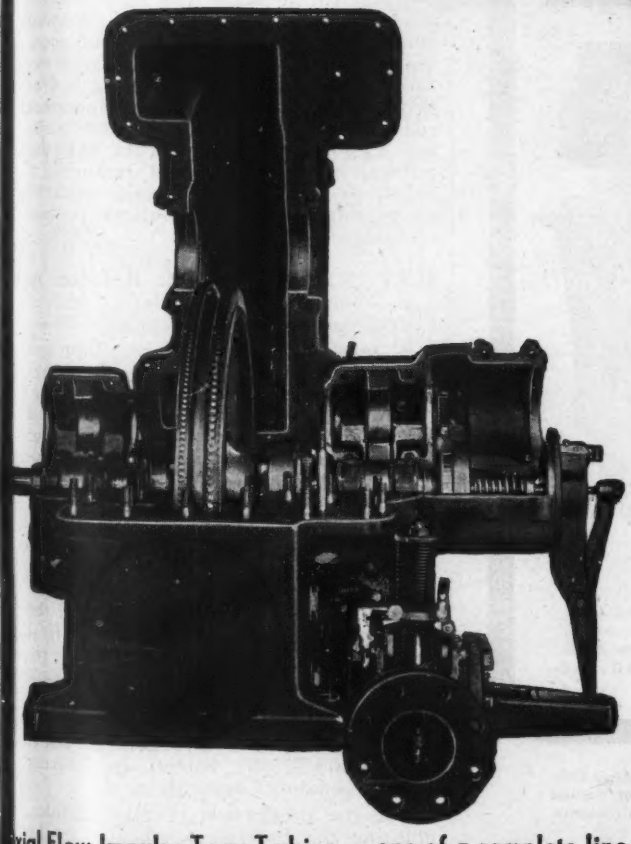
U.S.P. 2,331,915. Hydrogenation Catalyst. W. J. Kirkpatrick to Hercules Powder Company.

According to the invention, an improved supported noble-metal hydrogenation catalyst is prepared by coating the particles of a finely divided, inert, granular substantially non-porous support material with a mixture of a noble-metal nitrate and then heating to a temperature within the range of about 450-550° C. to effect reaction between the noble-metal compound and an alkali-metal nitrate and then heating to a temperature within the range of about 450 to 550° C. to effect reaction

TURBINE



1200 Horsepower Terry Multi-stage Turbine. Units of this type are employed extensively for driving large refinery pumps. The units may be designed for non-condensing, condensing, mixed pressure, or bleeder operation. They may be equipped with constant speed or variable speed governors, remote speed controls or with special governors to meet unusual requirements. Ask for Bulletin SR-114.



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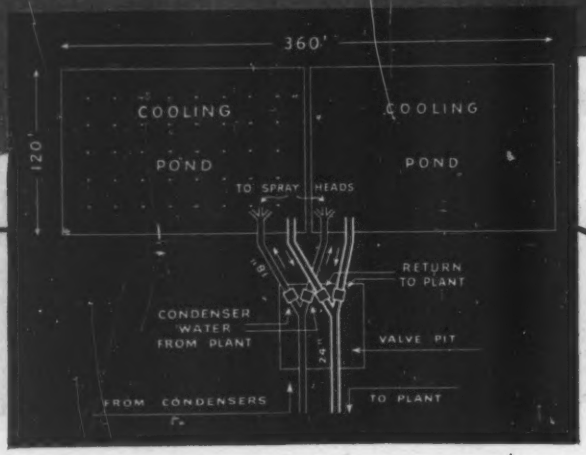

In this installation, four 18-inch motor operated butterfly valves (same as No. 527 illustrated below) are controlled by manual switches from the power plant. This arrangement permits the utilization of one or both cooling ponds or the quick draining of either or both.

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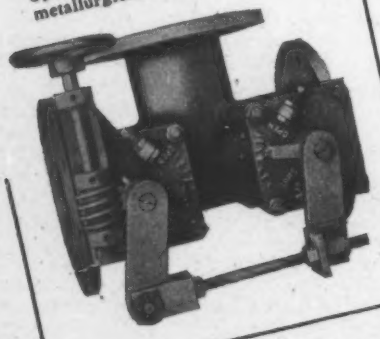

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R-S Streamlined BUTTERFLY VALVES

between the noble-metal compound and the nitrate with the resulting formation of the noble-metal oxide. Upon reduction with hydrogen, such a catalyst is ready for use as a hydrogenation catalyst.

U.S.P. 2,332,572. Process of Catalytic Hydrogenation. H. J. Hepp and J. P. Jones to Phillips Petroleum Company.

The process of catalytic non-destructive hydrogenation of unsaturated organic material in the liquid phase is claimed, which comprises passing a liquid mixture comprising unsaturated organic material to be hydrogenated together with a portion of a more volatile miscible inert hydrocarbon liquid to the top portion of a substantially vertical catalytic hydrogenation zone containing a hydrogenation catalyst and wherein a down-flowing liquid can pass countercurrently to an upflowing gas, passing a gas containing free hydrogen to the bottom portion of said reaction zone, maintaining in said zone reaction conditions such that the temperature is progressively higher from top to bottom and such that said unsaturated material is substantially completely hydrogenated in liquid phase and such that only a portion of said more volatile inert liquid vaporizes at the inlet to said zone and decreases in concentration in the liquid phase from the inlet to the outlet of said zone, passing to at least one intermediate point of said zone a liquid material comprising a further portion of more volatile inert liquid to dilute said unsaturated organic material being hydrogenated and to inhibit a temperature rise caused by heat of reaction, passing gases and vapors from the top portion of said zone, and removing a substantially saturated liquid material so produced from the bottom portion of said zone.

U.S.P. 2,333,500. Catalytic Reaction. A. B. Welty, Jr. to Standard Catalytic Company.

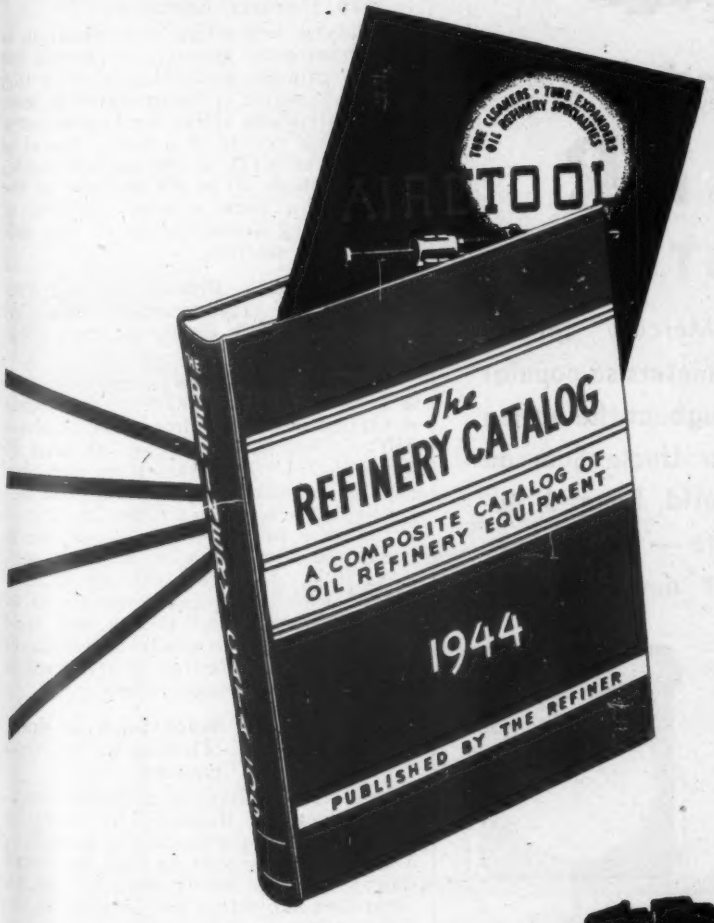
A method to prevent the injurious superheating of a hot regenerated hydrogenation catalyst, consisting e. g. of an oxide of a metal of group VI of the periodic system and a major amount of aluminum oxide, is described. Such catalysts often exhibit a substantial temperature rise on contact with hydrogen. By circulating a mixture of an inert gas containing initially 10-30 percent of hydrogen through the catalyst bed and then increasing the hydrogen content of the gas while controlling the catalyst temperature so that its final temperature is approximately the reaction temperature and not more than 1000 to 1100° F., overheating is avoided.

U.S.P. 2,334,033. Production of Alkyl Halides. E. W. Riblett to Process Management Corporation.

For the production of alkyl halides, chlorine and bromine are heated in the presence of an excess of low-boiling paraffin hydrocarbons, to effect termal conversion to alkyl halides and hydrogen halide. The products are fractionated and a portion of the hydrogen halide formed and of unconverted low-boiling paraffins are contacted with oxygen in the presence of a catalyst at elevated temperatures to effect conversion to alkyl halide and water. The thermal step is carried out at 1500° F., the catalytic step at 800° F. Suitable

Double Check the AIRETOOL SECTION of your 1944 Refinery Catalog

for



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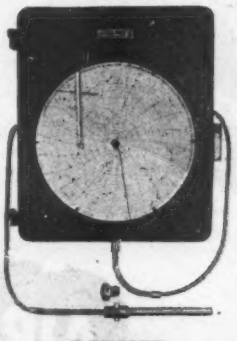

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catalysts are mixed oxides and chlorides of zirconium, cerium, thorium and silver on porous supports.

U.S.P. 2,334,872. Catalytic Conversion of Hydrocarbons. G. Free and W. V. Fuener to Alien Property Custodian.

The destructive hydrogenation of carbonaceous materials at 300-700° C. and elevated pressure is advantageously carried out in the presence of a catalyst containing silicic acid, obtained from a silica solution and at least one compound of a polyvalent metal, in the preparation of which the solution from which the hydrogel is formed has a hydrogen ion concentration lying between pH = 4 and pH = 7, and preferably between pH = 4 and pH = 6.5 during the formation of the hydrogel. The liquid from which the gel is formed must have this concentration throughout the whole duration of the gel formation. The proportion of gel in the catalyst should preferably amount to 30-75 percent.

U.S.P. 2,337,994. Catalytic Reactions with Carbonaceous Materials. F. Stoewener, E. Kennecke and F. Becke to Alien Property Custodian.

Catalytic destructive hydrogenation of a carbonaceous material is carried out with a catalyst containing a silica-rich mass into which is incorporated at least one catalytically active metal compound (such as a sulfide of a heavy metal of group V to VIII of the periodic table) and of which 30 to 85 percent of the total active pore volume consists of pores having diameters up to two millionth of a micron.

U.S.P. 2,338,119. Process for the Production of Hydrocarbon Oils. W. Kroenig and G. Grassl to Alien Property Custodian.

Catalytic destructive hydrogenation of a high-boiling carbonaceous substance is carried out at a temperature of above 350° C. and a pressure of at least 20 atmospheres by operating in the presence of a catalyst containing iron and consisting of a carrier substance and of a titanium sulfate which is soluble in water and dilute acid. In preparing such a catalyst, a carrier of any kind is soaked with an aqueous solution of an iron salt and titanyl sulfate and dried at moderately elevated temperatures (100-300° C.), if desired in a current of hydrogen or hydrogen sulfide.

U.S.P. 2,338,881. Reactivation of Spent Catalysts. C. L. Thomas to Universal Oil Products Company.

In the reactivation of carbonized catalysts which are damaged by excessive combustion temperatures, the method of lowering the amount of heat generated during the reaction is described which comprises subjecting the catalyst to hydrogenation until a major portion of the carbonaceous deposits has been hydrogenated and removed from the catalyst, and subjecting the thus partially reactivated catalyst to oxidation to burn an additional portion of the carbonaceous deposits therefrom.

U.S.P. 2,341,782. Treatment of Hydrocarbon Oils. V. N. Ipatieff and L. Schmerling to Universal Oil Products Company.

A process for destructively hydrogenating hydrocarbonaceous materials is described which consists in subjecting such materials at elevated tempera-

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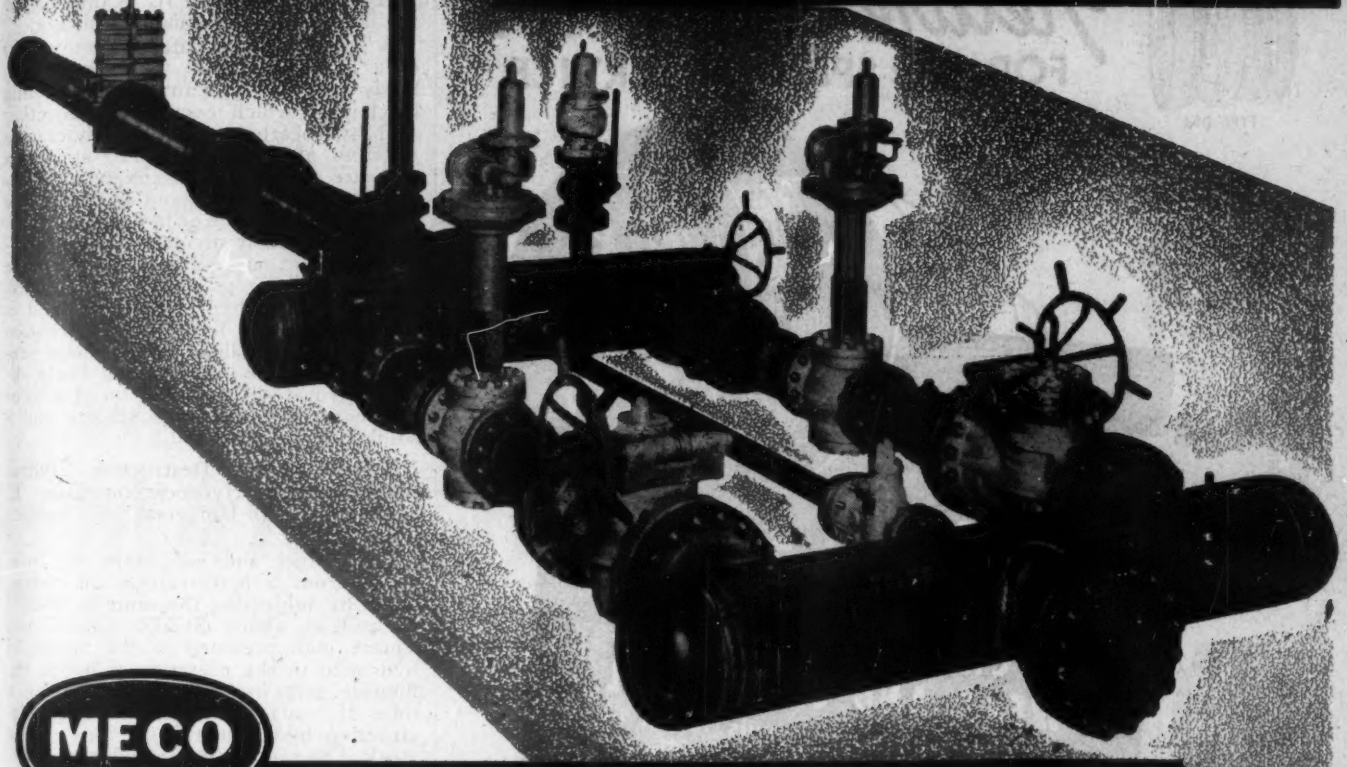

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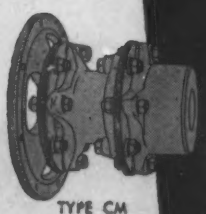
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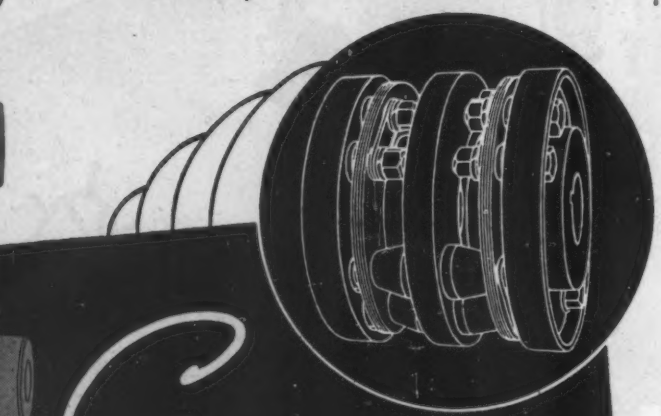

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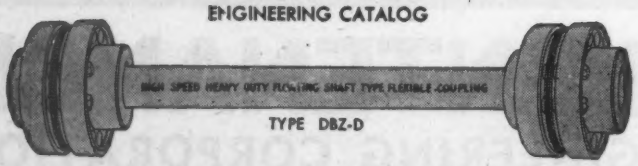

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WARREN, PENNSYLVANIA

tures and pressure and in the presence of hydrogen to contact with granular catalysts comprising essentially composites of zinc chloride and compounds of silica and alumina including certain natural silicates and those artificially prepared. The hydrogenation is effected at 100-500° C. and at 500-2000 pounds per square inch pressure.

U.S.P. 2,341,792. Catalytic Treatment of Hydrocarbons. E. R. Kanhofer to Universal Oil Products Company.

A process for the catalytic conversion of a hydrocarbon oil to produce relatively saturated high anti-knock gasoline is claimed which comprises subjecting said hydrocarbon oil at a temperature of from about 700-1150° F. and at a pressure of from approximately atmospheric to about 1000 pounds per square inch in the presence of hydrogen to contact with a finely divided catalyst, comprising silica, a hydrated metal oxide having cracking properties in combination with the hydrated silica, and a metal compound having hydrogenation properties, the silica having been precipitated as a non-gelatinous finely divided hydrate by acidification of a solution containing a soluble silicate and a soluble alkali-metal salt.

U.S.P. 2,344,789. Destructive Hydrogentaion of Hydrocarbon Oils. L. Schmerling to Universal Oil Products Company.

Motor fuel and iso-butane are prepared from a hydrocarbon oil charge stock by subjecting the same at 50-300° C. and at about 50-2000 pounds per square inch pressure to the action of hydrogen in the presence of boron trifluoride and hydrogen chloride for a time of contact sufficient to cause destructive hydrogenation of the charge stock. The process is particularly applicable to the treatment of gasoil distillates. When applied to the treatment of low-boiling gasolines, the process may be primarily directed to the production of low-boiling iso-parraffins.

U.S.P. 2,348,557. Treatment of Hydrocarbon Distillates. W. J. Mattox to Universal Oil Products Company.

A process for reforming gasoline of relatively low octane number to improve the octane rating is described which comprises subjecting the gasoline vapors mixed with hydrogen at a temperature of from about 475 to 525° C. and a pressure of from about 100-300 pounds per square inch and at a liquid hourly space velocity of from 0.5-20 to contact with a hydrogenation catalyst such as nickel on kieselguhr, effective in converting naphtenes to paraffins by hydrogenation. In a second stage the product from the first is contacted at dehydrogenating conditions with a dehydrogenation catalyst (vanadium oxide on alumina) to dehydrogenate aliphatic to cyclic hydrocarbons.

U.S.P. 2,348,702. Hydrogenation of Hydrocarbon Materials. L. Schmerling and V. N. Ipatieff to Universal Oil Products Company.

Higher-boiling hydrocarbon mixtures are subjected to contact with hydrogen in the presence of catalysts comprising essentially magnesium chloride to form lower-boiling hydrocarbons. The catalysts may consist of substantially anhydrous magnesium chloride in granular or powdered form or composite metals made by impregnating miscellaneous granular supports (alumina, bauxite,

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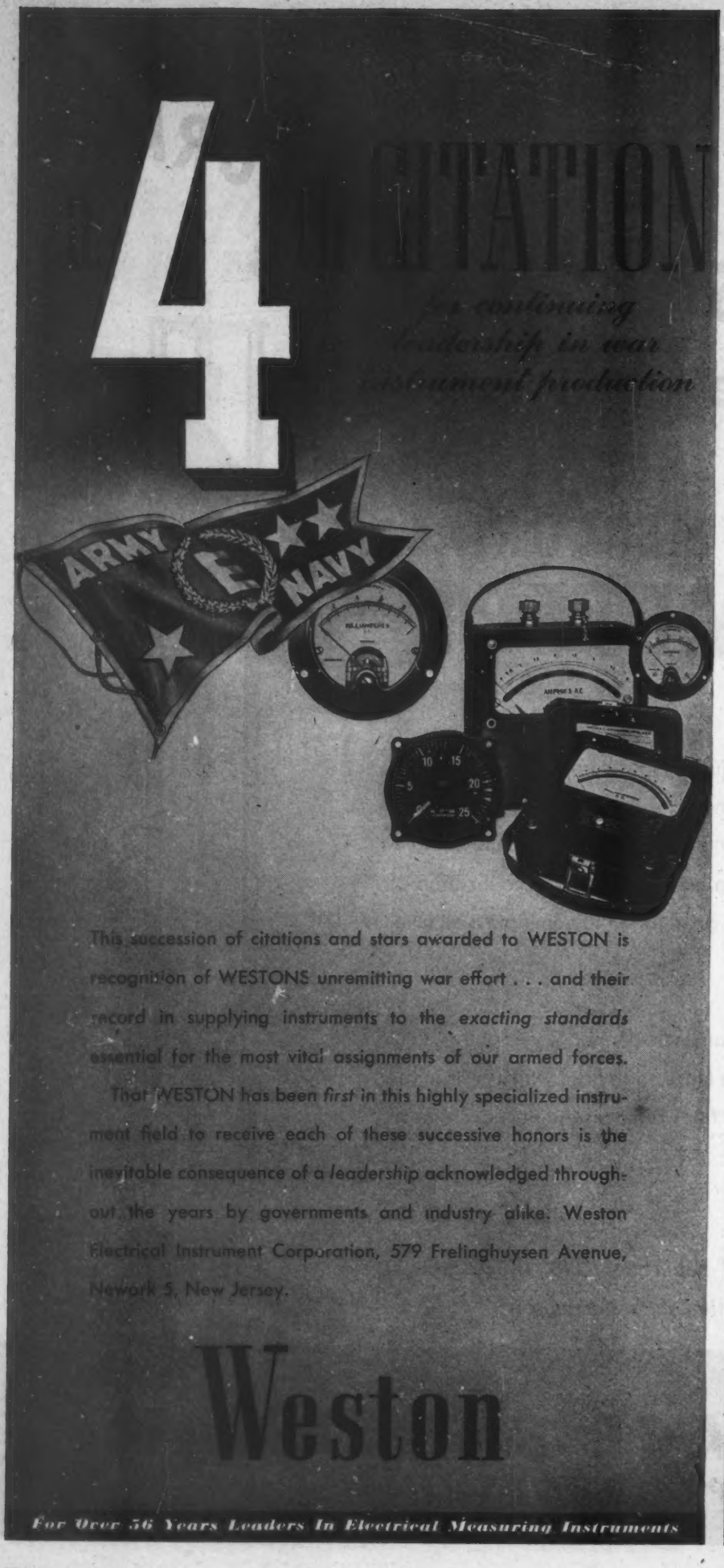
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kieselguhr, silica) with aqueous solutions of magnesium chloride. When the magnesium chloride solution retained on the support is evaporated, some hydrolysis of the magnesium salt occurs so that the resulting catalyst material comprises in addition to magnesium chloride, magnesium hydroxychloride and magnesium oxide. Catalyst of varying activity may thus be prepared. Temperatures of 350-450° C. and initial hydrogen pressure of 50-100 atmospheres are employed in the hydrogenation step.

U.S.P. 2,350,828. Conversion of Hydrocarbons. L. Schmerling and A. M. Durinsky to Universal Oil Products Company.

A process for the destructive hydrogenation of heavy hydrocarbonaceous materials to produce fractions of lower boiling range therefrom is described which comprises heating the hydrocarbonaceous materials under hydrogen pressure in the presence of alumina and hydrogen halides. These catalysts are not effected by sulfur. Instead of alumina other oxides of a refractory character such as zirconium oxide or thorium oxide may be used. Conversion is effected at 350-400° C. and 1-100 atmosphere pressure. Hydrogen chloride is employed in amounts of 0.5-50 percent by weight of the alumina.

U.S.P. 2,353,563. Halogenation Process. C. E. Hemminger to Standard Oil Development Company.

A process for the simultaneous production of ethyl chloride and ethylene dichloride is claimed which comprises reacting ethylene with a mixture containing about 90 mol percent of hydrogen chloride and about 10 mol percent of free chlorine at a temperature of about 40° C. and a pressure of about 15 pounds, gauge, in liquid phase, the reaction medium consisting essentially of a mixture of about 60 mol percent of ethylene dichloride and about 40 mol percent of ethyl chloride, such mixture containing in solution from about 1 percent to about 2 percent of aluminum chloride.

Hogge Heads Shell's Wood River Laboratory

A. C. Hogge, Jr., has been named chemist in charge of Shell Oil Company's Wood River Experimental Laboratory. Hogge joined the company in 1936 after graduation from Rice Institute, and in 1937 became a technical assistant at Norco refinery. The following year he was made a junior technologist at Houston refinery and in 1941 became assistant head stillman at that plant. In 1942 he was named technologist in the development section of manufacturing in the head office at St. Louis, from which position he moves to his present appointment.

Max W. Ball Special Assistant to Davies

Max W. Ball, Denver, has been appointed a special assistant to Deputy Petroleum Administrator Ralph K. Davies, to work on special assignments in all fields of oil operation as they affect government-industry relationships. Ball, an internationally known geologist and author, was for a period interested in mining and refining oil sands in Canada.

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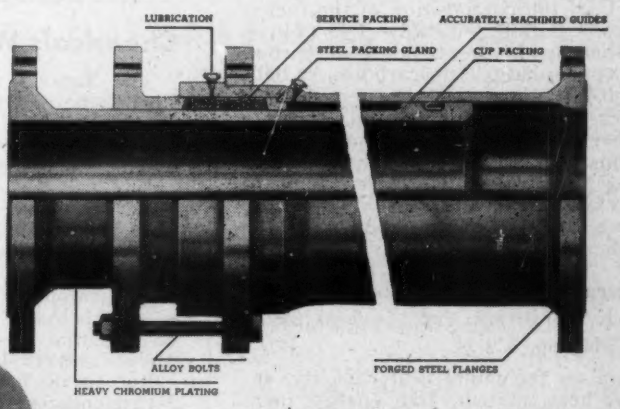

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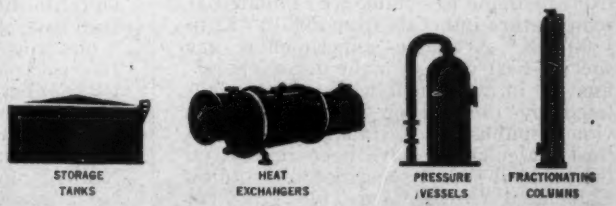

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Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Volume Correction Factors for C_4 Hydrocarbon Mixtures. C. S. CRAGOE. *Letter Circular LC-757, Natl. Bur. Standards,* July 27, 1944.

The circular presents a standardization of methods for correcting volumes of four hydrocarbons to standard units, i.e., gallons at 60° F. Tables are given for the approximate values of coefficient of expansion and other properties for 30 C_3, C_4, and C_5 hydrocarbons, for the vapor pressure of C_4 hydrocarbon mixtures, for the weights per gallon corresponding to designated specific gravity at 60°/60° F., for liquid volume correction factors for C_4 hydrocarbon mixtures, and for vapor volume correction factors for C_4 hydrocarbon mixtures. The circular can be obtained from the National Bureau of Standards without charge.

The Specific Heat of 100-Octane Fuel in the Gaseous State. H. M. SPIERS. *J. Inst. Fuel* **17** (1944) p. 130.

The author derives a formula for the calculation of specific heats at 0° and 100° C. if the composition of the fuel is known. C_p at $0° = 0.4028 - 1.43/(14n + 2)$ where n is the number of carbon atoms of aliphatic hydrocarbons. At 100°, $C_p = 0.482$ when n is greater than 2. Values are given for C_p and C_v for a number of aliphatic and aromatic hydrocarbons at 0° and 100° C. Specific heat values thus calculated were found to agree fairly well with those obtained by Bahlke and Kay's expression from the specific gravity of the fuel.

Thermodynamics of Gaseous Paraffins. K. S. PITZER. *Ind. & Eng. Chem.* **36** (1944) pp. 829-31.

Data on the molal heat capacity, entropy, heat content, free energy functions and specific heat of the paraffins from methane to octane are tabulated at temperature intervals from 298.16° K. to 1500° K. Available experimental gas specific-heat values for the normal paraffins are in agreement with values calculated by the author by method previously published. Certain parameters in these calculations have been revised on the basis of recent spectroscopic studies. Calculated entropies are in agreement with measured values. The data for branched paraffins are too few to allow generalizations except that the change in specific heat with isomerization is small. Entropy differences calculated previously have been confirmed, in so far as additional data are available. A bibliography of 19 references is included.

The Heats of Combustion of Some Substituted Eicosanes, Heneicosanes and Docosanes. J. W. KNOWLTON AND H. M. HUFFMAN. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1492-4.

The work reported is part of the general program of the Bureau of Mines to determine the thermodynamic properties of petroleum hydrocarbons. The presently reported work covers the combustion of ten hydrocarbons that appear in the light-lube oil range of petroleum. The isothermal heats of combustion at 25° C. of 3-phenyleicosane, 9-phenyleicosane, 3-cyclohexyleicosane, 9-cyclohexyleicosane, 11-cyclopentylheneicosane, 11-phenylheneicosane, 11-cyclohexylheneicosane, 5-n-butyldocosane, 11n-butyldocosane, and 11-n-decylheneicosane were determined. The heats of formation of the compounds, were calculated. The calorimetric method used in the work has been described previously. The hydrocarbon samples were prepared under Research Project 42 of the API at Pennsylvania State College. The data secured in the work are presented in tabular form.

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The National Registry of Rare Chemicals, Armour Research Foundation, Thirty-third, Federal and Dearborn Streets, Chicago, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only in one gram quantities, please inform the Registry.

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3-Benzeneazo-p-cresol
2,4-Bisbenzeneazo phenol
Di (chlormethyl) ether
Butylene, amylene, hexylene chlorohydrins
Di cresyl phthalate
1,1-Dichloro propane
Ethyl gallate
Furfurylamine
Molybdenum oxychloride
Norhydroguaiaretic acid
Nonadecanoic acid
Thallium trichloride (2.2 kg)
n-Undecanoic acid
Vinyl acetonitrile

The Application of Free Energy Equations to the Study of the Synthesis of Hydrocarbons from Carbon Monoxide and Hydrogen. W. W. MYDDLETON. *Jour. Inst. Petr.* **30** (1944) pp. 211-24.

Equations were derived relating free energy of reaction to temperature in the synthesis of a series of gaseous hydrocarbons from carbon monoxide and hydrogen. In formulating these equations molecular heat-temperature curves were drawn for each reactant and product and molecular heat-temperature equations were fitted over the range 25-250° C., existing equations being generally unsatisfactory for the temperature range covering synthesis. Some use was made of molecular heat and entropy values calculated from statistical and spectroscopic data. the suppression of reactions in which carbon dioxide is formed, in spite of free energy changes favorable to these reactions, is attributed to special conditions prevailing at the catalyst surface. The appearance of traces of ethylene among the products of synthesis instead of appreciable quantities predicted by the free energy relationships is explained by the incorporation of ethylene as formed into the hydrocarbon chains that are building. The possibility of increasing the yields of isobutane and isobutene is considered worthy of study. The formation of aromatic hydrocarbons requires a special orientation of reactants on the surface of the catalyst, and the probability of the necessary conditions ocurring is slight. The author presents tables of the data employed in his calculations covering statistical and spectroscopic data, molecular heat at constant pressure, standard molecular entropy, heats of combustion, free energy equations of reactions, and molecular free energy of formation of gaseous hydrocarbons from carbon monoxide and hydrogen. A bibliography of 56 references is appended.

Vapor-Liquid Equilibria of Close-Boiling Binary Hydrocarbon Mixtures. A. R. RICHARDS AND E. HARGREAVES. *Ind. & Eng. Chem.* **36** (1944) pp. 805-8.

Vapor-liquid equilibrium data for binary systems of hydrocarbons boiling in the neighborhood of 80° C. are given. The system benzene-2,4-dimethylpentane

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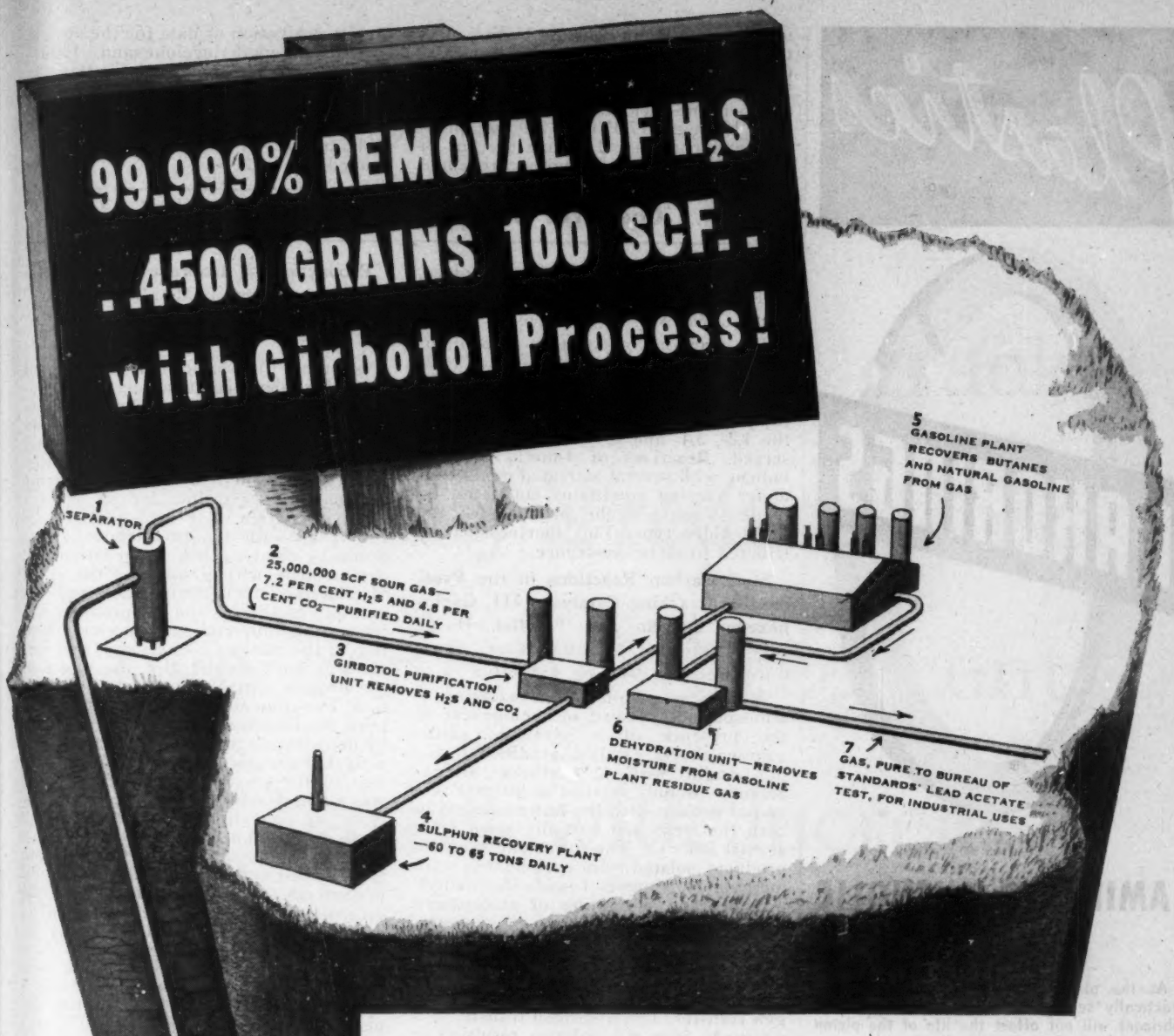
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formed a minimum constant boiling mixture giving an azeotrope boiling at 75.2° C. and 757 mm. pressure and contains 54.5 mole percent of benzene. The system benzene-cyclohexane gives an azeotrope boiling at 77.4° C. at 759 mm. pressure and contains 51.5 mole percent of benzene. Analytical difficulties prevented precise evaluation of data for the system cyclohexane-methylcyclohexand. Equilibrium data are presented in detail in tabular form, as well as the properties of the hydrocarbons and the refractive indices of the hydrocarbon solutions. A bibliography of 39 references is appended.

Chemical Compositions and Reactions

Reactions of 4-Methyl-1,3-pentadiene, G. B. BACHMAN AND R. E. HATTON. *Jour. Amer. Chem. Soc.* **66** (1944 pp. 1513-14.

The reactions of 4-methyl-1,3-pentadiene with bromine, sulfur dioxide, a diazonium salt, phosphorus pentachloride, and hydrogen have been investigated and the products characterized. Additions to the 1,2-, 3,4- and 1,4-positions were observed. Reactions of 4-methyl-1,3-pentadiene with several activated mono-enes under varying conditions could not be made to yield cyclic products of the Diels-Alder type. This inertness is attributed to steric hindrance.

Hydrocarbon Reactions in the Presence of Cracking Catalysts. III. Cyclohexene, Decalin and Tetralin. H. S. BLOCH AND C. L. THOMAS. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1589-94.

A study was made of the reactions, at atmospheric pressure, of cyclohexene in the presence of a synthetic silica-alumina-thoria catalyst at 250-400° C.; of tetralin with a synthetic silica-alumina-zirconia catalyst at 400-500° C.; and of decalin with the latter catalyst in both the fresh and partially spent state at 400-500° C. The principal reaction products isolated from cyclohexene were methylcyclopentenes-1 and -2, methylcyclopentane, a mixture of unidentified liquids higher boiling than cyclohexene, and 2,6-dimethylnaphthalene. The principal reactions of cyclohexene under the conditions studied were (1) isomerization, (2) polymerization and (3) hydrogen transfer. The hydrogen transfer was primarily from the polymer resulting in the formation of dimethylnaphthalenes and the hydrogenation of the methylcyclopentenes to methlycyclopentane. Naphthalene was the product formed most abundantly from tetralin. Scission of the hydro-aromatic ring gave benzene, toluene, xylenes, possibly ethylbenzene, and higher boiling alkylated benzenes. No alkenylbenzenes were isolated. They may have been formed and then converted into the corresponding alkyl derivatives by hydrogen made available by the conversion of tetralin to naphthalene. Some of the tetralin was converted to bicycloparaffins, presumably decalin or its isomers. The products can be explained by reactions of (1) scission of the hydroaromatic ring and (2) hydrogen transfer. Apparently, isomerization also occurred, for the xylene fraction contained xylenes other than o-xylene. The chief products formed from decalin were "isodecalins," C_3 and C_4 olefinic and paraffinic gases in which isobutane predominated, methyl-cyclopentane, and probably cyclohexane and the corresponding olefins. In addition, tetralin or its isomers was found and the aromatic reaction products of tetralin conversion indicated above. The products can be explained by the following reactions of decalin and the intermediate tetralin: (1) isomerization, (2) ring scission and (3) hydrogen transfer.

Production of Isoprene by Catalytic Dehydrogenation. J. M. MAVITY AND E. E. ZETTERHOLM. *Jour. Inst Petr.* **30** (1944) pp. 473-85.

Isoprene, the basic hydrocarbon of natural rubber, is attracting more interest in the synthetic rubber field. Its utilization as a component of butyl rubber in all probability foreshadows other future applications. The lack of a satisfactory cheap method for manufacturing isoprene is responsible for its present small utilization. The investigation was concerned with the production of isoprene by catalytic dehydrogenation and deals chiefly with a study of the effect of charigng stock composition and operating conditions on isoprene yield. Since in commercial operation regeneration of the catalyst is necessary, this factor was studied, and also the effect of the process variables on carbon deposition. The isopentane used was 99 percent pure, the isopentenes used were obtained by dehydrating tertiaryamyl alcohol over activated alumina, followed by fractionation of the product. The catalyst used was a commercial dehydrogenation catalyst, pre-aged by twenty-one days of service in a pilot plant dehydrogenating butane. The apparatus used in the work is described and pictured. The analytical procedures are outlined. In general, decreasing pressure increases the yield of isoprene. Decrease of space velocity increases conversion. An increase in temperature increases conversion. The yield of isoprene under recycling conditions is indicated as 80 percent or higher depending o nthe conversions and conditions of operation. The process is preferably conducted at reduced pressure, at temperatures of about 615-660° C. and employs feed stocks comprising either isopentane, isopentenes, or mixtures of these components.

Exchanges of Halogen and Hydrogen Between Organic Halides and Isoparaffins in the Presence of Aluminum Halides. P. D. BARTLETT, F. E. CONDON AND A. SCHNEIDER. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1531-42.

The experiments reported constitute part of a study of the mechanism of low-temperature paraffin alkylation. In the presence of aluminum bromide halogen-hydorogen exchanges take place between tertiary or secondary alkylhalides and isoparaffins. For example, t-butyl chloride, isopentane, and aluminum bromide are converted into isobutane, t-amyl bromide, and aluminum chloride in the shortest time in which mixing can be effected. This time is estimated to be of the order of 0.001 second. As the duration of contact is increased, the t-amylbromide is partly isomerized into 2 bromo-3-methylbutane and numerous products appear typical of low-temperature catalytic paraffin alkylations. Halogen-hydrogen exchanges have been realized using isobutane, isopentane, 2,3-

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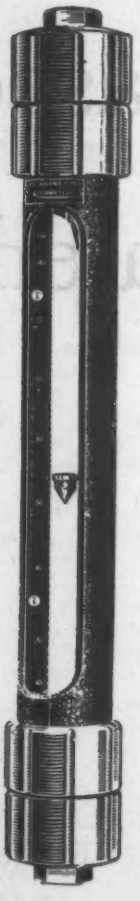

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dimethylbutane, 2,2,3-trimethylbutane, methyl- and iso-propylcyclohexanes, and decalin. Aluminum chloride as well as the bromide is effective. Poorly characterized products were obtained with 2,2,4-trimethylpentane, hydrindane, cholestane, camphane and bicyclo (2,2,1)-heptane. A mechanism for the halogen-hydrogen exchange is proposed by which a carbonium ion is depicted as removing hydrogen from the tertiary position in an isoparaffin. The exchange is thus regarded as an intermolecular analog of a process for which there is evidence in intramolecular rearrangements. The demonstrated existence of the halogen-hydrogen exchange makes it possible to propose a mechanism of paraffin alkylation comprising only steps that involve well-known types of reaction, and utilizing principles of reaction mechanism already amply demonstrated, notably by the work of Whitmore and his collaborators. This mechanism is outlined and its possible application to alkylation is indicated. The experimental work is described in some detail.

The Arylbutadiene-Maleic Anhydride Reaction. R. T. ARNOLD AND E. C. COYNER. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1542-5.

Maleic anhydride was allowed to react with three arylbutadienes each of which has two active diene groups. The aryl substituent consisted of 1-naphthyl-3,4-dimethoxyphenyl, and 3,4-methylenedioxyphenyl. Unfortunately, the pure dienes polymerized so rapidly that they could not be isolated as such; consequently, the diene in each case was formed during the course of the reaction by dehydration (with maleic anhydride) of the appropriate alcohol. Experimental data are given in some detail and the structural representation of the reaction is depicted. Structural determination proves that maleic anhydride reacts preferentially with the aliphatic side chain.

Manufacture: Processes and Plant

Fractional Distillation of Binary Mixtures, Simplified Computation of Theoretical Plates and Transfer Units. A. J. V. UNDERWOOD. *Jour. Inst. Petr.* **30** (1944) pp. 225-42.

Equations in convenient form for numerical computation, are derived for determining the number of theoretical plates or transfer units required for the separation of binary solutions of normal volatility. When the top or bottom product contains only a small amount of one of the components, computation can be simplified by using certain approximate equations that give satisfactory accuracy. By a simple transformation a calculation for a stripping column can be converted into one for a rectifying column. The derivation of the equation is given in detail, and the numerical results of the computation for a rectifying column and a stripping column are tabulated in typical examples.

Multicomponent Fractionation: A Simplified Approach to Plate-to-Plate Calculations. H. H. HUMMEL, *Jour. Inst. Petr.* **30** (1944) pp. 445-71.

Rigorous results for multicomponent fractionation are obtained by what is essentially a modified and more convenient plate-to-plate calculation. The procedure retains the accuracy of a plate-to-plate method and at the same time eliminates much of the detail and labor ordinarily associated with this accuracy. A temperature gradient is assumed throughout the column, and successive approximations are made to the temperature gradient until a satisfactory check is obtained. Two or three trials are usually necessary. The method of calculation is particularly suited for predicting the performance of an existing tower, although it is also useful for calculating the number of plates required to make a desired separation. It will be of greatest value where the usual plate-to-plate calculations are otherwise required, especially when there are a number of distributed components. A new form of absorption factor chart, for use when rapid approximate results are desired, is given. While attention is given in the main to ideal systems, a suggested approach in the case of non-ideal systems is outlined. The data and computations for typical problems are presented in tabular and graphical form.

Hydrocarbon Reactions in the Presence of Cracking Catalysts. II. Hydrogen Transfer. C. L. THOMAS. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1586-89.

n-Octenes were subjected to the action of a cracking catalyst under conditions that give chiefly paraffinic products. It was shown that hydrogen transfer occurred in the absence of any added cycloparaffins. The hydrogen transfer resulted in the formation of paraffin and aromatic hydrocarbons as well as a carbonaceous catalyst-deposit poor in hydrogen. At least 50 percent of the hydrogen needed to acount for the paraffins found came from the catalyst-deposit. Reactions of isomerization, cyclization, and polymerization or condensation accompanied the reaction of hydrogen transfer. The experimental work is described in some detail. Data are given for the composition and quantities of the gases and liquid products. The catalyst used was silica-alumina-zirconia prepared by a method described. The author believes that the reactions described in the article aid in understanding the chemistry of the processes involved in making aviation fuel, in which gasoline containing olefins are contacted with cracking catalysts at temperatures in the range of 350 to 525° C. and at pressures somewhat above atmospheric to produce an improvement in the anti-knock quality of the fuel. Under these conditions the olefin content of the gasoline is reduced, the aromatic content increased, and the susceptibility to tetraethyl lead improved.

Chem. & Met.'s 11th Report on Materials for Process Equipment. *Chem. & Met. Engr.* **51** (1944) pp. 93-131.

This is the 11th biennial report of Chemical and Metallurgical Engineering on material of construction for chemical engineering equipment. Special emphasis is placed on corrosion experiences. More data are presented on the resistance of more materials to corrosion than in any

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of the previous reports. The report opens with a recital of the experiences of chemical engineers in 60 typical plants in the process industries on corrosion experiences. This is summarized in a tabulation covering the materials of construction regarded as suitable for different types of equipment when in contact with various corroding chemicals. A directory of metals, listing most of the metallic materials used for the construction of process equipment is next appended. The name of each material is accompanied by the name and address of the manufacturer, nominal chemical composition, and the forms in which the material is available. The table also gives the primary purpose of the material, whether for corrosion or abrasion resistance. The tabulation is cross-referenced to a second table that gives the resistance of metals to 80 corrosive chemicals. The tabulation of the 80 chemicals gives materials that have been found to resist their corrosion. This tabulation is cross-indexed to the directory of metals that precedes it. A tabulation is then presented covering nonmetallic materials. This includes name and address of manufacturer and designation of the products. This tabulation covers structural carbon and graphite. chemical stoneware, porcelain, and acid-proof brick and stone, glass, glass-lined and fused silica, plastics, rubber and similar products, and wood.

Dehydration of Commercial Gases by Solid Adsorbents. R. G. CAPPELL, E. G. MAHHERSCHMIDT AND W. W. DESCHNER. *Ind. & Eng. Chem.* **36** (1944) pp. 779-84.

Operating and laboratory data are presented with respect to the solid adsorptive dehydration of commercial gases. The four adsorbents tested were 4-8 mesh silica gel, activated alumnia grade A, florite (a natural bauxite selected for mechanical strength and adsorptive capacity), and Hi-florite (florite impregnated with 12-14 percent manganous chloride). The apparatus used is described. The loss in adsorptive capacity of the adsorbents is given as a function of time or number of reactivations. The natural gas dehydrated was passed from the inlet header of a commercial installation and piped to the packed scrubber of the test unit. The reactivation gas was supplied to test unit from the commercial plant reactivation gas heater. Data are given on the adsorptive capacity of the adsorbent, on the effect of temperature of the gas on the adsorptive capacity, on the pressure drop through the adsorbent bed, and on the reactivation requirements. Plant operating data are included for the dehydration of natural gas containing 0.2 gallons of gasoline per 1000 cubic feet. The effect of impurities on the gas is briefly considered, particularly that of hydrogen sulfide. Hydrogen sulfide concentration of 5 grains per 100 standard cubic feet of gas can be tolerated successfully by the adsorbent. Concentrations of 40 grains have made replacement of adsorbent necessary after several months of operation. Gases containing hydrogen sulfide and oxygen in appreciable concentrations are difficult to dry because the hydrogen sulfide is rapidly oxidized to sulfur and water under adsorbent reactivating temperature conditions. The unvaporized sulfur coats the adsorbent and causes gradual loss in adsorptive capacity. Gases to be dried should be cooled as far as possible with water, since water removal in the range 100-120°F. can be accomplished more economically by cooling than by means of a solid adsorbent. A bibliography of 28 references is included.

Products: Properties and Utilization

Rheological Properties of Asphalt. R. N. TRAXLER, H. E. SCHWEYER, AND J. W. ROMBERG. *Ind. & Eng. Chem.* **36** (1944) pp. 823-9.

The flow characteristics of twenty-seven asphalts from different sources and processed by various methods were evaluated in rotary viscometers of a type suitable for the measurement of high consistencies at a constant rate of shear. Asphalts from Gulf Coast, Texas, Mexican, California, Mid-Continent and Venezulean crudes were included. Consistencies of each asphalt at fixed temperatures were determined at two or more rates of shear. If an asphalt is a complex liquid, the measured consistency was found to decrease as the rate of shear increased. The magnitude or degree of complex flow can be evaluated by c in the equation, $M = F/Sc$; c is unity for asphalts that are simple (Newtonian) liquids but varies from unity for those that are complex of non-Newtonian liquids. This equation was found to be valid over a considerable range in rate of shear and is not limited to one type or size of viscometer. Data are given that show that certain asphalts are simple liquids at service temperatures, while others have the characteristics of complex liquids. Evidence is given that the type of flow (and if complex, the degree) depends on the source of the asphalt, the method and degree of processing, the age of the sample, and the temperature at which the evaluation is made. It is shown that some asphalts retain their complex flow characteristics at temperatures as high as their ring and ball softening point. The relations between the fundamental rheological characteristics of asphalts and the empirical tests commonly used by bituminous technologists are illustrated. A bibliography of 18 references is included.

Sulfuric Acid Extraction in Hydro-Carbon Type Analysis. C. C. ALLEN AND H. W. DUCKWALL. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 558-60.

Type analysis of hydrocarbons boiling above the gasoline range has recently assumed importance, in keeping with the development of new petroleum cracking processes and high-solvency petroleum solvents. The extrapolation method based on acid extraction is suggested as a means of routine and control analysis of paraffin - naphthene - aromatic or paraffin - naphthene - aromatic - olefin mixtures low in olefin concentration and boiling in the kerosene-to-gas-oil range. The procedure as described is suitable for hydrocarbon solutions containing 20 percent or less of aromatics and olefins. When applicable, the extrapolation method gives a direct measurement of

A view of one of many plants designed and constructed by Petroleum Engineering, Inc., in the past 15 years of continuous service to the industry. Petroleum Engineering, Inc., Offices: Tulsa and Houston.

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By Robert Yarnall Richie

AN INVITATION . . . and a promise

Send for this new 24-page Downingtown bulletin on the design and fabrication of heat exchangers. We think it will be a helpful addition to your files on heat transfer equipment. In it you will find—

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saturate content and properties. This is sufficient, when taken together with a molecular weight determination, to determine the paraffin-naphthene ratio. At the same time a measure of olefin plus aromatic content is obtained and approximations as to the character of the unsaturates can be made. The procedure is described in some detail and the results of typical extractions with various types of hydrocarbons to be extracted are given. The author's estimate that the volume percent of unsaturates can be estimated to within ±0.2 percent accuracy.

A Precision Head for Small Fractionating Columns. R. S. Towne. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 584-5.

The author is of the opinion that the most satisfactory head for laboratory columns of all kinds is the total condensation partial take-off type. This head is not subject to the mechanical difficulties inherent in heads of the partial condensation total take-off variety. It is particularly adaptable for use with fractionating columns that distill small samples, since the holdup is negligible if the head is properly constructed. The details of a head of this type are given in some detail in the context and are shown in drawings that are dimensioned for construction.

Navy Still Needs Oil Inspectors and Supervisors

The Navy has a continuing need for officers who are qualified for duty as Petroleum Inspectors or as Oil Terminal Supervisors.

The Petroleum Inspectors should have a degree in petroleum or chemical engineering, plus two years actual refinery or laboratory experience in the analysis of petroleum products. In lieu of the degree, consideration will be given to applicants who have ten years in responsible positions in the oil refinery field or laboratory experience in connection with fuel oil and its derivatives.

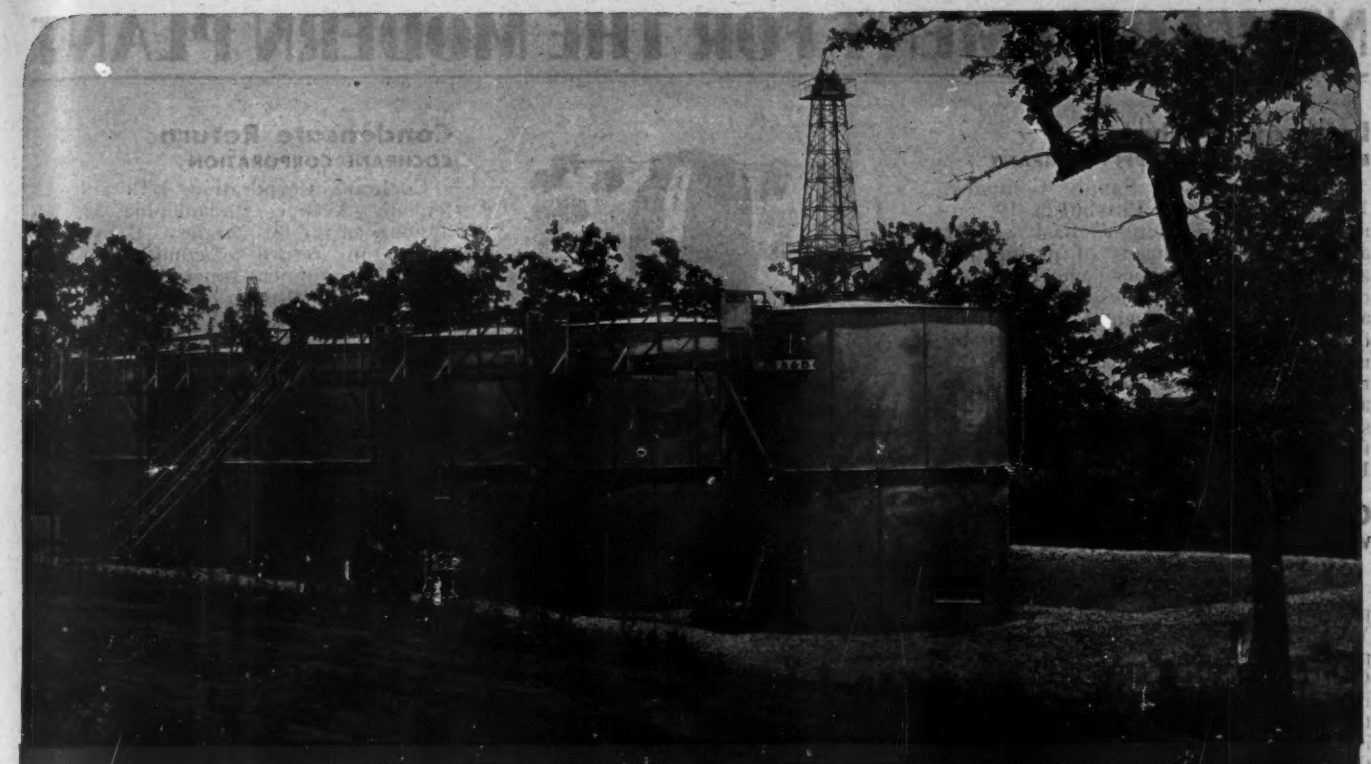
Oil Terminal Supervisors should have had at least two years of college and a knowledge of the specifications of gasoline, fuel oil, lubricants and aircraft engine oil. They must have had at least five years experience in the handling of bulk fuel oil and at least two years experience in a water terminal storage plant in a supervisory capacity. It is essential that they have a knowledge of loading and unloading tankers of large capacity.

The age bracket for petroleum Inspectors is 23 to 45 years and for Oil Terminal Supervisors 30 to 50 years. Candidates must meet basic Naval physical requirements.

Application should be made at the nearest office of Naval Officer Procurement. These offices are located in principal cities throughout the United States.

Marshall Becomes President Ashland Oil & Refining

J. Howard Marshall has been elected president of Ashland Oil & Refining Company, Ashland, Kentucky, succeeding Paul G. Blazer who becomes chairman of the board. James L. Martin, who has been board chairman, has been made vice chairman. Marshall, member of a San Francisco law firm, recently has been chief counsel and assistant administrator of PAW at Washington.



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Bolt and Tank Sealers developed by Presstite Engineering Company are now being used by the United States Army and Navy for sealing storage tanks for aromatic gasoline in locations throughout the world.

To the oil industry, Presstite also offers plastic compounds and cements, all highly resistant to the action of aromatic gasoline, oil, water, etc., plus oil and gasoline resistant coatings to prevent corrosion on the inside of storage tanks.

Presstite compounds are being used extensively to seal aircraft fuel tanks against aromatic fuel, one of the toughest sealing jobs ever encountered.

Whatever your sealing problems in the oil industry, for tanks, pipe fittings, connections, or any other applications, bring your problems to *Sealing Specialists*. We'll gladly work with you and your engineers if you'll send us detailed information on your sealing requirements.

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PRESSTITE ENGINEERING COMPANY

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NEW EQUIPMENT FOR THE MODERN PLANT

Laboratory Shaker

BURRELL TECHNICAL SUPPLY COMPANY

Burrell Technical Supply Company, 1936 Fifth Avenue, Pittsburgh 19, announces a "wrist-action" flask shaker as a mechanical means of performing a tiresome laboratory chore. Twin clamps for holding flasks up to 1000 ml are mounted on a central shaft. The degree of shaking is controlled by movement of a knob which varies the motion from gentle swirling to violent agitation, in all degrees simulating the snap of wrist action. Sizes are available for 8, 12 or 16 flasks, for operation on 110 or 220-volt current.

Chemicals

WESTVACO CHLORINE PRODUCTS CORPORATION

Westvaco Chlorine Products Corporation, 405 Lexington Avenue, New York is introducing a new chemical product for the refining industry, Granular Magnesol, which is available in two grades, one as a dessicant and the other as a percolant. In addition to its uses in these capacities, this synthetic magnesium silicate the manufacturer suggests that it may have application as a catalyst and catalyst supporting agent.

Water-Analysis Apparatus

CHIEF CHEMICAL CORPORATION

Chief Chemical Corporation, 1123 Broadway, New York 10, is offering the "Aero-Titrator," a rapid water-analysis apparatus which has been in use by the Army for three years and is just now being offered commercially for use by plant operators and laboratory technicians for determination of hardness, calcium and magnesium in waters.

An announcement says that false endpoints are absent and air agitations eliminates shaking by hand, and accuracy is comparable with gravimetric methods. Operation is simple. It makes use of a new endpoint, based on the foam-meter principle, this endpoint being unmistakable and reproducible with a high degree of precision, determinations being made in 10 minutes.

The instrument is supplied calibrated and ready for assembly and use. There are no moving parts or delicate features to go out of adjustment, and vital parts are durable plastic.

Samples of 50 ml or less are required.

Transformer

SOLA ELECTRIC COMPANY

Sola Electric Company, 2525 Clybourn Avenue, Chicago 14, has announced a small, compact, hermetically-sealed constant-voltage transformer for through-chassis mounting, designed for such applications as heating and refrigeration controls, vacuum-tube volt-meters, electronic gauging and inspection equipment, photo-metric instruments and similar applications where precisely regulated supply voltage is mandatory. At any reasonable transformation ratio of input to output it will provide a single output voltage constant to within ± 1 percent of rated requirements regardless of line voltage

Burrell Flask Shaker

variations as great as ± 12 to 15 percent. Capacities up to 15 VA, 60 cycle operation are available and are supplied with a separate capacitator unit for external mounting. The transformer has no moving parts, requires no manual supervision or adjustments, and is self-protecting against short circuits.

Level Control

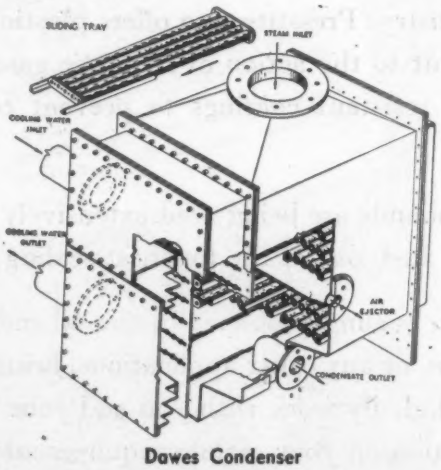
MANNING, MAXWELL & MOORE

Hancock Valve Division of Manning, Maxwell & Moore, Bridgeport, Connecticutt, has announced the Hancock electric level float control, which it claims gives accurate and dependable liquid level to within a fraction of an inch, and is automatically and mechanically trouble-free. There are no levers, linkages, bellows, stuffing boxes, cooling fins, mercury switches or wearing parts. By adjusting of a screw the level of the liquid can be raised or lowered.

Condenser

CONTRACT ENGINEERING

Contract Engineering, San Francisco, announces production of the Dawes Condenser, said to incorporate new economies in condenser design. The tubes are approximately a third as long as those in conventional condensers and are of special extruded surface construction. Tubes are built in a series of trays in "file-cabinet" manner, and individual trays of tubes can be removed for cleaning and repair in a small working area.



Dawes Condenser

Designs call for units up to 10,000 pounds of steam per hour at whatever vacuum is desired up to 29 inches Hg. Units may be manifolded to aggregate desired capacity, and units may be cut in or out as needed, and replacements substituted without shutdown.

Condensate Return

COCHRANE CORPORATION

Cochrane Corporation, 17th and Allegheny Avenue, Philadelphia 32, has announced the "Cochrane C-B System," a unit for return of condensate from process equipment operating at pressures up to 200 pounds directly back to the boiler without flash loss and with all the sensible heat contained in the original steam. Fuel savings of from 10 to 15 percent are claimed, boiler pressure more easily maintained, and boiler capacity increased. Higher production rates are made possible by a patented jet pumping principle. All condensate, non-condensible gasses and entrained air are handled by the jet at high temperature with a constant differential maintained across the equipment creating positive drainage, with entrained air automatically discharged from the closed circuit before return to the boiler. There is no appreciable pressure drop in the steam chambers. Hence, heat-transfer rates are higher and more uniform, resulting in hotter heating surfaces, and greater production at the same steam pressures with less fuel costs.

Overload Control

GENERAL CONTROLS COMPANY

General Controls Company, Glendale, California, has devised a manual reset valve with over-limit control for installation with the regular gas-operated valve with controlling limit control and pilot generator to prevent overruns in temperature. As an example, if the controlling limit control for the regular gas valve is set at 380° F., the over-limit control for the additional manual reset valve would be set higher than 380°, but lower than the danger point on the particular installation. Then should dirt or other foreign matter prevent the main controlling valve from operating, the second shut-off control would go into operation and eliminate the hazard of too-high temperature.

Variable-Speed Drive

LOMBARD GOVERNOR CORPORATION

Lombard Governor Corporation, 60 East 42nd Street, New York 17, announces a variable-speed drive which differs from the conventional in that it uses the V-belt as a control medium only rather than for both drive and control, primary speed reduction being accomplished by conventional gearing methods. Through this gearing arrangement 90 percent of the power goes through conventional gears while only 10 percent passes through the V-belt, a minimum load which avoids slippage. Low gear ratio affords hairline control, insuring peak production speeds. Low maintenance is made possible as the easily accessible V-belt is the only part likely to need replacement over a long period. Efficiency at low speeds is equal to if not higher than the efficiencies usually obtained. Having the variable-speed output shaft furnished concentric with the motor shaft gives it the advantage of a direct-line drive. Remote control is available, with horizontally split casings optional.

The reducer is scarcely larger than

Replacements are fewer with molybdenum cast steel return bends.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

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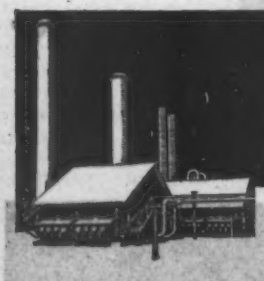
Paradoxically, fireproof construction results from fire. From the discovery of mortar for the Pyramids by burning gypsum, on through the ages to the manufacture of modern Portland Cement, fire has been a pre-requisite in making fireproof masonry materials. Equally essential is the use of fire in petroleum refining. With skillful engineering and research Alcorn has for 20 years met the increasingly complex demand of the changing techniques in processing every type of petroleum product. Alcorn installations in major refineries throughout the world are today setting new records for top performance at lower operating costs. Consider the merit of Alcorn's experience and knowledge for the solution of your heating problems.



ALCORN
Combustion Company

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the motor with which it is used, even in the higher horsepowers, the complete unit with motor having the size and appearance of two standard a-c motors coupled together. Gears are totally enclosed and run in oil.

Safety Valve

FARRIS ENGINEERING COMPANY

Farris Engineering Company, Palisades Park, New Jersey, announces development of a line of venturi-type safety valves with special provisions for constant accurate blow-off, exceptionally great capacity, complete tightness of re-seating, minimum escape of vapor into the surrounding space, and elimination of angular distortion and fouling.

The inlet venturi-tube nozzle of this design gives an unobstructed port and guided high velocity of the steam, which results in high lift and correspondingly great capacity. A "separator bell" causes the steam to make three changes in direction before passing into the atmosphere, and includes a drain for the condensed moisture into the body, minimizing escape of vapor. The "separator bell" also helps to keep the spring cool by preventing steam from striking the spring, and improves freedom and maintenance of alignment by providing for higher support of the spring.

Insulated Wire

UNITED STATES RUBBER COMPANY

United States Rubber Company, Rockefeller Center, New York, has announced multiple-conductor wire and cable, insulated with a special Buna-S synthetic rubber latex. The new product has a much thinner insulating wall allowing 20 percent more footage of wire or cable per reel, an important improvement for field operations.

Simplified Practice for Relief Valves Approved

The proposed Simplified Practice Recommendation for Iron and Steel Relief Valves for Petroleum, Chemical and General Industrial Services, has been approved for promulgation, according to an announcement by the Division of Simplified Practice, National Bureau of Standards. It is identified as R205-44.

The valves covered by this recommendation are primarily intended for air, gas, vapor and liquid service requirements for oil refineries, gasoline plants, synthetic-rubber projects, and chemical plants. Some types are suitable for general industrial service.

Development of this recommendation was undertaken at the request of the Shipbuilding Division of the War Production Board, and is one of several such recommendations proposed for the purpose of insuring adequate production of all types of safety and relief valves for all needs.

The Petroleum Administration for War is the principal claimant agency for the relief valves found in the proposed recommendation and representatives of the construction division of that office collaborated with the segment committee of the Valve Industry Advisory Committee and the National Bureau of Standards in drafting the simplified list of sizes and varieties.

Until printed copies are available, a limited number of mimeographed copies of the recommendation may be obtained from the Division of Simplified Practice, National Bureau of Standards, Washington 25, D. C.

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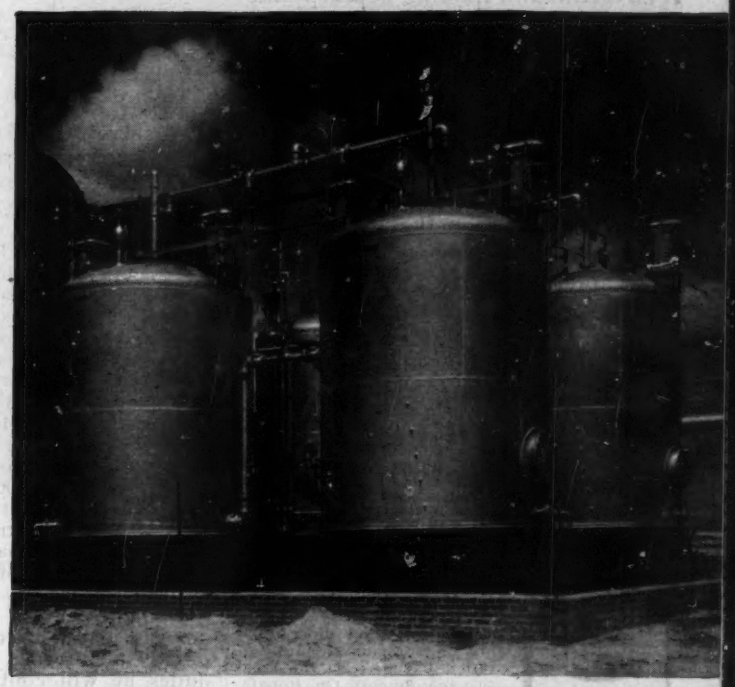
DESALTING RESULTED IN OUTSTANDING OPERATING IMPROVEMENTS

- ★ 86.6% Efficient Salt Removal (45 p t b to 6)
- ★ 900% Increase In On-Stream Time (3 days to 30)
- ★ Plugging due to salt eliminated
- ★ Corrosion from evolved HCL reduced
- ★ Quality of finished product improved (asphalt solubility)

The experience of this Arkansas refiner is just one of many examples of improved refinery operations brought about by Petreco Desalting. In refineries all over America Petreco Desalting is repeatedly eliminating salt plugging, preventing scaling, reducing corrosion, improving products and increasing on-stream time. These are times when inefficiency cannot be tolerated...if your charging crude is salt-bearing in *any* degree, discuss the situation with a Petreco engineer. He can tell you the results Petreco is getting on similar salt contents.



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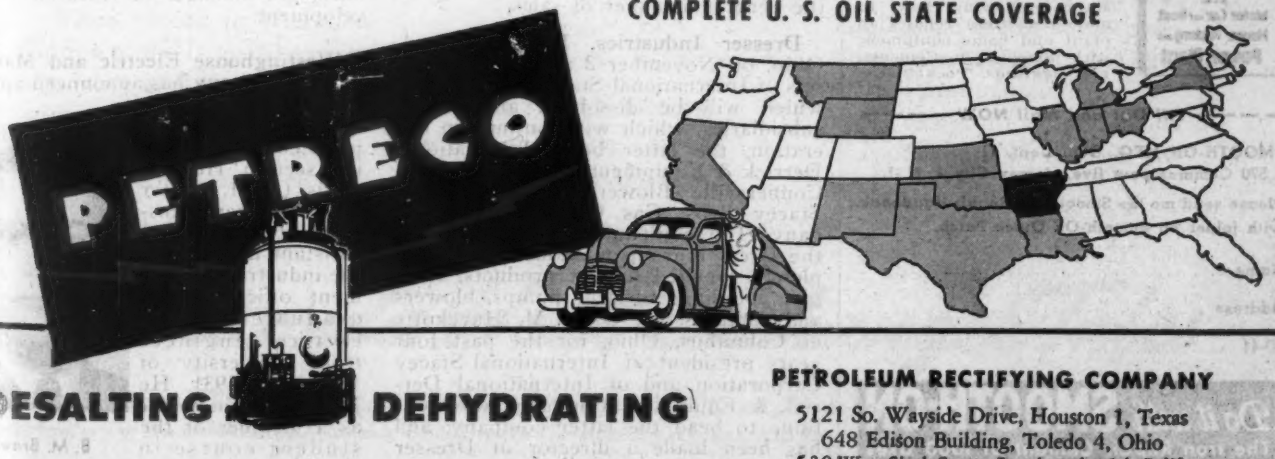

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☆ BUSINESS NOTES ☆

Hooker Electrochemical Company, Niagara Falls, New York, has announced appointment of Herbert Heesch to its sales staff in the northern area of New Jersey. Heesch graduated from the University of Rochester as a chemical engineer in 1932 and joined the sales staff of Hooker Electrochemical Company in 1933, serving in the Eastern states until 1937. Prior to his recent appointment he was a salesman with Heyden Chemical Corporation.

Herbert Heesch

Conoflow Corporation, recently organized with R. B. Werey as president, has opened offices and manufacturing facilities at 2100 Arch Street, Philadelphia, for manufacture and sale of devices for regulation and control of flow, and sale of specialized equipment of other manufacture used by the oil, gas and chemical industries. Werey, a graduate of the University of Michigan, is a member of the American Institute of Chemical Engineers. Until recently he was in charge of sales to the petroleum industry for The Brown Instrument Company.

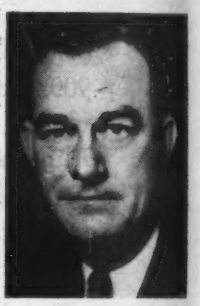
Pittsburgh Equitable Meter Company-Merco Nordstrom Valve Company, Pittsburgh, has announced appointment of J. E. Brown as assistant to A. J. Kerr, general manager of sales. All of Brown's business experience since graduation from Ohio University 38 years ago has been with this organization. He joined Pittsburgh Equitable Meter Company in 1906, and upon consolidation of that company with Merco Nordstrom Valve Company in 1926 he was made manager of the Chicago district office. The following year he returned to Pittsburgh as director of sales and of advertising. In 1942 he was placed in charge of the home office sales order department, which duties he will continue as assistant to the general manager of sales.

J. E. Brown

Dresser Industries, Inc., Cleveland, Ohio, on November 2 acquired the assets of International-Stacey Corporation, which will be dissolved, and of its subsidiaries, which will continue in operation, the latter being International Derrick & Equipment Company, Roots-Connersville Blower Corporation and Stacey Bros. Gas Construction Company. Ten companies now comprising the Dresser group manufacture a completely rounded line of products, from pipe couplings to large pumps, blowers and compressors. Oscar M. Havekotte of Columbus, Ohio, for the past four years president of International-Stacey Corporation and of International Derrick & Equipment Company, will continue to head the latter company, and has been made a director of Dresser Industries, Inc. Havekotte, after education at the University of Pittsburgh, began his business career with Carnegie Steel Company, and was assistant treasurer of Carnegie-Illinois Steel Corporation when he made his present connection.

Diamond Alkali Company, Pittsburgh, has purchased Emeryville Chemical Company, 405 Montgomery Street, San Francisco, and will continue manufacture of silicate of soda, sodium metasilicate, and silicate compounds at the plant at Emeryville, California. Stanley Pedder and Charles Eckland continue as president and vice president of the company, and no changes in personnel are contemplated except that Howard R. Bauer will be transferred from the Diamond Alkali Company's San Francisco organization to be general manager of Emeryville Chemical Company.

Elliott Company, Jeannette, Pennsylvania, has announced election of R. W. Owens as vice president in charge of manufacturing. He joined the company as assistant to the president in February of this year, having previously had a wide experience of 28 years in design and manufacture of electrical products. Frank H. Stohr has been appointed assistant to the president to succeed Owens. Stohr joined Westinghouse Electric and Manufacturing Company after graduation from University of Iowa as an electrical engineer in 1922, and advanced to manager of that company's industry sales department, which position he help up until joining Elliott Company.



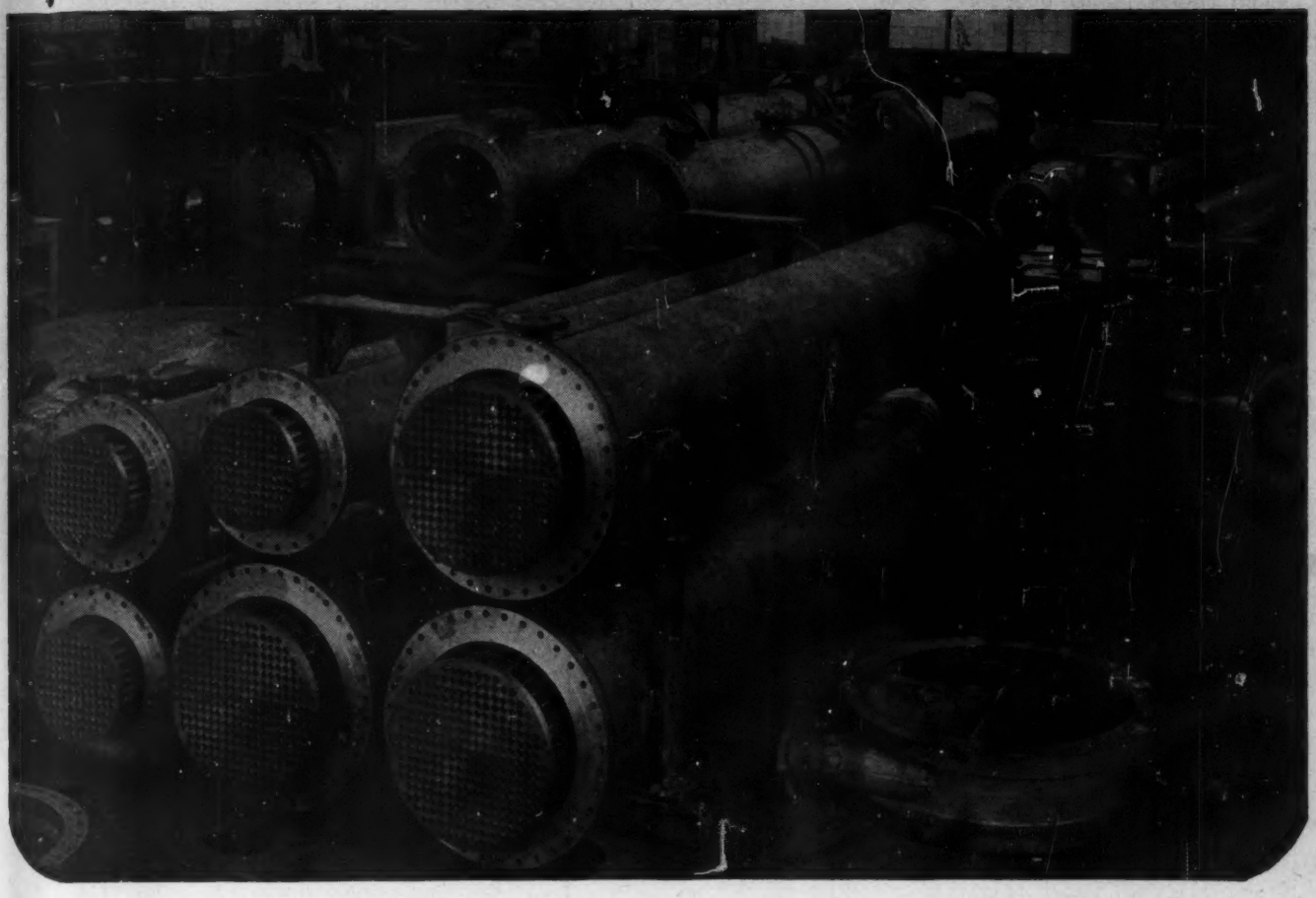
R. W. Owens

Pennsylvania Salt Manufacturing Corporation, Chestnut Hill, Philadelphia, dedicated its new Whitemarsh Research Laboratories in a program of visitation from October 4 to October 7. During the four days, groups from various branches of science and industry visited the new facilities. C. F. Kettering, General Motors research division, made an address the first day, when Leonard T. Beale, company president, presented the key to the laboratory to Dr. S. C. Ogburn, Jr., manager of research and development.

Westinghouse Electric and Manufacturing Company has announced appointment of B. M. Brown as manager of the petroleum and chemical section. He succeeds Q. M. Crater who has been transferred to Detroit as assistant manager of the industrial department office. Brown graduated as an electrical engineer from University of Illinois in 1931. He joined Westinghouse as a member of the student course in

B. M. Brown

Condensing, cooling, reheating by Anaconda Admiralty Tubes



THESE heat exchangers, nearing completion in the shops of the J. P. Devine Manufacturing Company, division of H. K. Porter Company, Inc., at Mt. Vernon, Illinois, are all tubed with Anaconda Admiralty Metal Condenser Tubes.

When placed in operation for one of the large oil companies, they will be required to withstand the corrosive action of condensing, cooling and reheating hydrocarbons as well as to provide rapid, efficient heat transfer.

The wide variety of specialized copper alloys, the engineering experience and research facilities provided to so many manufacturers and users of heat transfer equipment are at your service. Publication B-2 lists Anaconda Condenser Tube Alloys, describes manufacturing processes, compositions and fields of application. We'll be glad to send you a copy. 44199

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★ **Buy more than before** ★

★ **to shorten the war** ★

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ANACONDA

Anaconda Heat Exchanger Tubes

THE AMERICAN BRASS COMPANY—General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company—In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*

TIME AND MONEY ARE SAVED WHEN

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Users of Kellogg Castables —KASTIC and KEL-CRETE reduce furnace shut downs by making their own special shapes, jambs, door linings, baffle walls, ducts, dampers, car tops, etc. by simply adding water to the scientifically prepared Kellogg mixture. No waiting for delivery of special shapes from a distant point.

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KEL-CRETE...

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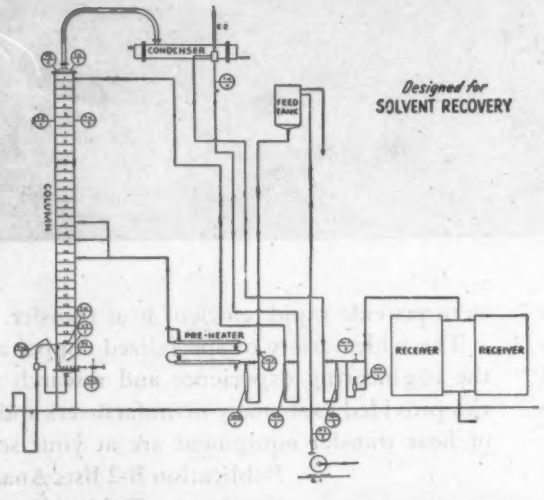

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1941 and then served in the machinery electrification section until 1943. During that year he left the company to work with Pomona Pump Company, Pomona, California, but returned to work in the transportation department where he remained until his present appointment.

Ansul Chemical Company, Marinette, Wisconsin, announces that its owned and operated subsidiary, **Dugas Engineering Corporation,** has become the Dugas Division of the parent company. John A. Sargent has been appointed planning engineer for both units to coordinate progress and expansion after the war. Sargent has been with Wisconsin Public Service Corporation since 1920, except for a four-year period, 1924-28, when he attended the University of Wisconsin to obtain a degree in electrical engineering.

J. A. Sargent

Foster Wheeler Corporation, 165 Broadway, New York 6, recently has acquired the services of Wayne C. Edmister as a process engineer in its petroleum division. During the previous 15 months, Edmister was in Washington with Rubber Reserve Company as supervisor of utilities for government-owned synthetic rubber plants. Before going to Washington he was for 9 years connected with Standard Oil Company (Indiana) at Whiting, Indiana, as a process design group leader in the research department. He is a graduate of Oklahoma A. & M. College and Cornell University.

Graver Tank & Manufacturing Company, East Chicago, Indiana, has appointed Ben D. Pennington manager of its West Coast office at 908 South Atlantic Boulevard, Los Angeles. His major interest will be directed toward the construction field in which he has had extensive experience, particularly on the Pacific Coast. Recently he completed supervising construction of a catalytic cracking plant in California.

B. D. Pennington

The Timken Steel and Tube Division, The Timken Roller Bearing Company, Canton, Ohio, announces appointment of A. F. Sprankle as metallurgical engineer of the division. He formerly was manager of the alloy bureau of Carnegie-Illinois Steel Company in the Pittsburgh district. A graduate of Ohio State University, B.S. in metallurgical engineering, Sprankle has done three years of laboratory work at Batelle Memorial Institute, Columbus, Ohio. In 1934 he first joined The Timken Roller Bearing Company, specializing in bearing and high-temperature steels. While in Pittsburgh he gave a series of lectures on alloy steels to post-graduate students at Carnegie Institute of Technology night schools. Besides ASM and AIME memberships, he has been active on the following committees: AISI-Alloy Technical Committee, Ferrous Metal-

Lake Charles Refinery of Cities Service Refining Corporation, one of the world's largest and most modern. Approximately 4,455 tons of NATIONAL Pipe and Tubing were used in its construction.

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lurgical Advisory Board, Sub-committee on Gun Forging, Bearing Sub-committee and General Purpose Sub-committee of WPB's Technical Advisory Committee, and various project committees of the National Research Council.

F. C. H. Vaughan

Yarnall-Waring Company, Philadelphia 18, announces appointment of F. C. Harry Vaughan to the company's Midwest sales office at 510 North Dearborn Street, Chicago. In addition to 6 years of industrial sales work, Vaughan served for 14 years as chief engineer in three plants of a large Western meat packing company.

Hills McCanna Company, Chicago, announces appointment of D. D. Foster Company as its representative in the Pittsburgh area, with offices at 412 Peoples Gas Building, Pittsburgh 19.

The Patterson-Kelley Company, East Stroudsburg, Pennsylvania, has announced appointment of Mid-Coast Sales Company, Esperson Building, Houston, to handle sales of its heat exchangers and special equipment for the petro-chemical industries. Mid-Coast Sales Company recently was organized by Bernard F. Fallon.

The Foxboro Company, Foxboro, Massachusetts, recently has employed Robert Beers on its sales force covering the New York-New Jersey territory out of its New York office at 420 Lexington Avenue (17). After graduation from Yale (Sheffield) in 1924, Beers spent several years in the production department of Western Electric Company, followed by similar experience with American Brass Company and with Whitehead Metal Products. For the past two years he has been with WPB at Washington.

J. P. Devine Manufacturing Company and Mt. Vernon Car Manufacturing Company, units of H. K. Porter Company, Inc., announce appointment of William W. Greenway as production engineer. He has been production specialist for Austin Western Company.

Pacific Pumps, Inc., is the new corporate name of Pacific Pump Works, Huntington Park, California. The corporate name of Mid-Continent Pumps Supply Company, Tulsa, has been changed to Pacific Pumps, Inc., Mid-Continent Division.

H. K. Porter Company, Inc., and subsidiaries have opened offices at 849 Petroleum Building, Los Angeles 15, with Harold A. Hintz as district manager, handling sales and engineering service for H. K. Porter Company, Inc., and Porter Process Division, Mt. Vernon Car Manufacturing Company, Devine Manufacturing Company, Quimby Pump Company, Fort Pitt Steel Casting Company and Porter-Blairsville Company. Hintz had his engineering education at University of Chicago, and for a number of years operated as Harold Hintz Company, industrial property management specialists. More recently he was sales engineer for Axelson Manufacturing Company, Los Angeles. The company has

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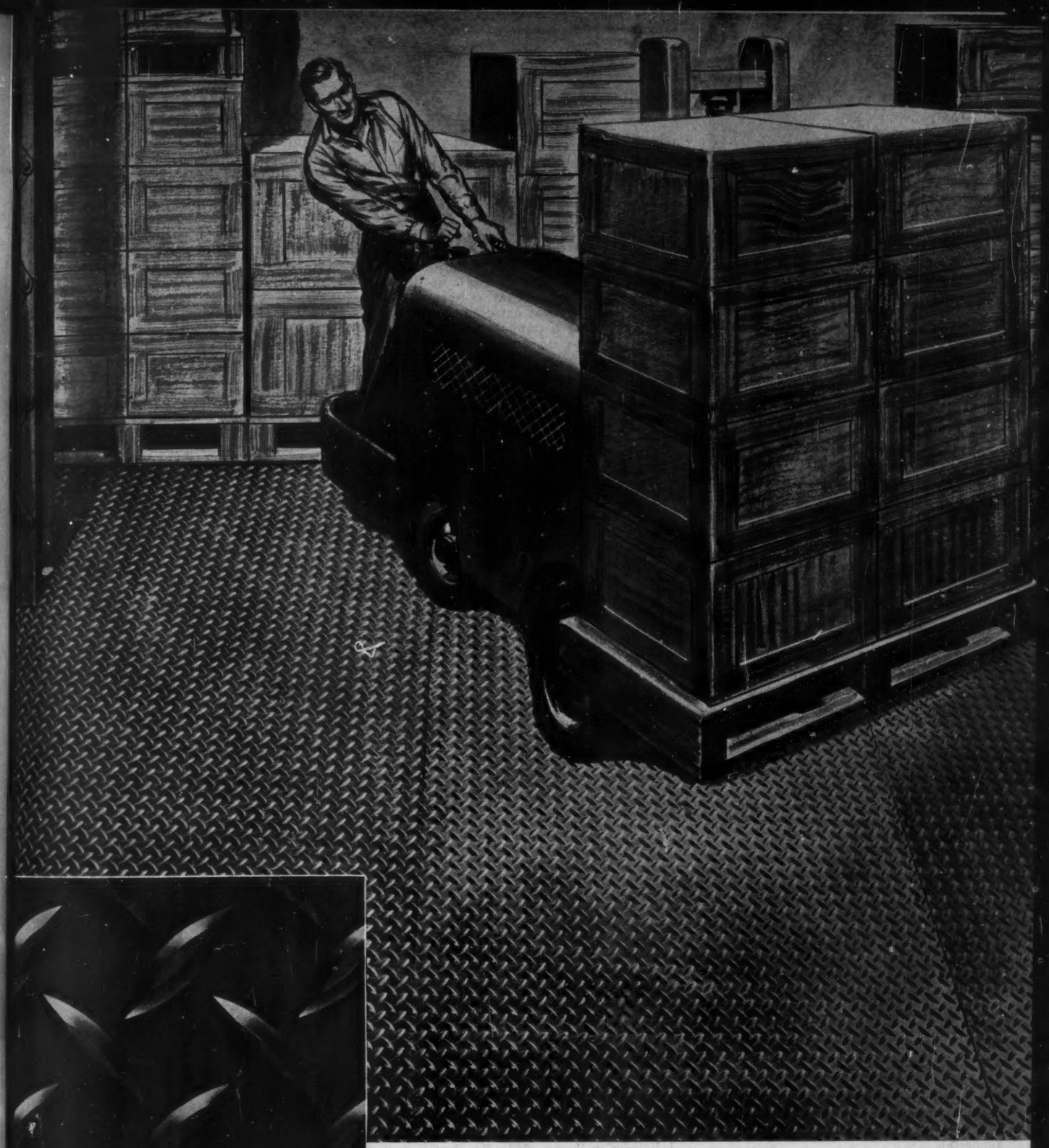

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Every City Official, Engineer and Plant and Factory superintendent had better be ready and willing to go along in a lot of new changes for the active days of postwar. Your America is going to be a pretty alive and progressive country. Things are going to happen very rapidly.

There is one mighty big and important fact that all should remember: . . . all progress, growth and development will absolutely depend upon an adequate and thoroughly dependable supply of water.

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DEEP WELL PUMPS

BUILDERS OF WELL WATER SYSTEMS FOR INDUSTRIES AND MUNICIPALITIES

said that plans also are in the making for an office at San Francisco.

The Atlas Lumnite Cement Company announces appointment of Roy T. Giles, service director, as sales manager. Giles joined the North Carolina highway organization in 1921, first as materials engineer and later testing engineer. He joined Blaw-Knox Company, Pittsburgh, as chief engineer of concrete control and in 1928 joined the Atlas Lumnite Cement Company. He has spent much of his time in the development of refractory concrete. Giles has written several articles on the subject, including a paper presented at the annual meeting of the American Ceramic Society.

The Foxboro Company, Foxboro, Massachusetts, has added Frank Renner to the sales staff working out of its Southern California office at 2307 East Eighth Street, Los Angeles. Renner's recent experience has been with a West Coast company servicing industrial instruments.

American Brake Shoe Company has announced appointment of Robert B. Parker as assistant to the president. His duties include research on sales and coordination, and responsibility for liaison between the company's metallurgical and research laboratories and the sales and production staffs of the company's 59 plants. Parker is a graduate of Hotchkiss School and Yale University.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933

Of PETROLEUM REFINER published monthly at Houston, Texas, for October, 1944.

STATE OF TEXAS,
COUNTY OF HARRIS, ss:

Before me, a Notary Public in and for the State and county aforesaid, personally appeared A. L. Burns, who, having been duly sworn according to law, deposes and says that he is the Business Manager of PETROLEUM REFINER and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Publisher, Ray L. Dudley, 3371 Chevy Chase, Houston, Texas.

Editor, Grady Triplett, 2113 Albans Road, Houston, Texas.

Managing Editor, J. Kent Ridley, 612 Branard, Houston, Texas.

Business Manager, A. L. Burns, No. 7 Chelsea Place, Houston, Texas.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock.)

The Gulf Publishing Company, Houston, Texas; James Anderson, Houston, Texas; A. L. Burns, Houston, Texas; Jas. F. Carter, Jr., Tulsa, Okla.; Mrs. Mary Margaret Cashman, Houston, Texas; Bayard T. G. Dudley, Houston, Texas; Estate of Dr. N. L. Dudley, Deceased, Houston, Texas; Ray L. Dudley, Houston, Texas; Estate of W. S. Farish, Sr., Deceased, Houston, Texas; Wm. V. Gross, Utopia, Texas; Mrs. Anita S. Lane, Houston, Texas; Chas. H. Lane, Houston, Texas; Tom W. Nelson, Houston, Texas; Wallace E. Pratt, New York, N. Y.; J. Kent Ridley, Houston, Texas; Mrs. Maud G. Sterling, La Porte, Texas; R. P. Swinsky, New York, N. Y.; O. R. Waller, Chicago, Ill.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

A. L. BURNS, Business Manager.

Sworn to and subscribed before me this 21st day of September, 1944.

P. J. AUCOIN,
(Seal) Notary Public, Harris County, Texas.
(My commission expires June 1, 1945.)

Jones & Laughlin Steel Corporation has organized a subsidiary, Jones & Laughlin International Company, to act as sales representative in Brazil. It is to simplify business procedure in connection with shipments from the United States and also indicates a general intention on the part of corporations to intensify exports after the war.

American Die Casting Institute has been given the Ordnance Distinguished Service Award in recognition of its contribution to the war effort.

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